PDS® Products

BN-975 Wafers

Low Defect Boron Diffusion Systems

The purpose of the hydrogen injection process is to increase die yield per wafer. This is accomplished because the effects associated with the hydrogen injection process. These effects are 1) improved uniformity across the wafer, across the run and run to run; 2) control of defects such as oxidation induced stacking faults and point defects simultaneous to the deposition process. The successful implementation of the hydrogen injection process has been shown to produce higher yields than other methods of boron deposition, helping to improve process cost effectiveness.

PROCESS FOR HIGH TEMPERATURE APPLICATIONS

For High Temperature Applications: PDS®-BN-975* wafers with 2-step hydrogen injection offer flexible applicability that can be used for process temperatures of more than 1000°C. The 2-step hydrogen injection process can be used for deep isolation diffusions, bases for power transistors, bases for linear polar devices and other applications. It allows one set of sources to be used for all boron processes, regardless of temperature.

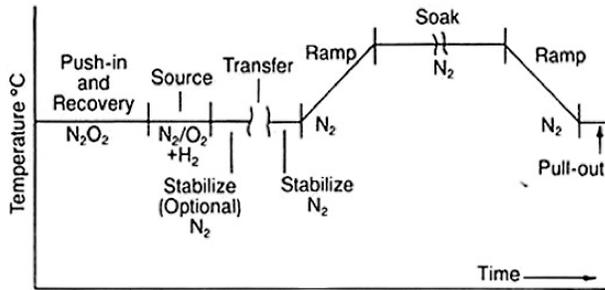### PROCESS OUTLINE FOR HIGH TEMPERATURE BN-975 2-STEP H_2 INJECTION

Step	Ambient	Time	Function
Recovery	N_2/O_2 (50%/50%)	15 min.	Thermal Equilibrium Thin Oxide Growth
Source	Add H_2 1-2%, Vol.	1-2 min.	Dopant Glass Transfer
Transfer	Room	30 min. (<20 Min. Preferred)	Seperate Si Wafers to Quartz Boat for High Temp Soak
Soak	N_2 (100%)	30 min.	Defect Control Resistivity Target
Deglaze	10:1 HF	Variable	Remove Unreduced Boron Glass
Low Temperature Oxidation (LTO)	O_2	20 min.	Remove Si-B Layer and Defects
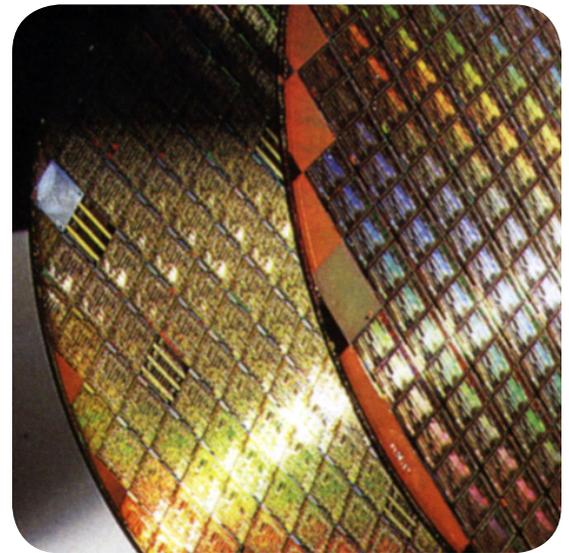
Features/Benefits

- Extreme flexibility that allows application to many device structures, thereby eliminating capital expense in device conversion.
- Improved yields by gettering oxidation induced stacking faults and improved uniformity across the wafer, across a run and from run-to-run.
- Precision chemical principles make for predictability and repeatability through the controlled introduction of moisture in the diffusion tube, even at temperatures as low as 750°C.
- Moisture modulation of the vapor pressure of the B_2O_3- HBO_2 system causes a rapid flux of gas, creating excellent uniformity and allowing a damage control mechanism to be established simultaneous to the deposition process.
- Successful application of the PDS-hydrogen injection process throughout the semiconductor industry.
- A trained staff is maintained to assist in all technical needs and support.

BORON NITRIDE

SAINT-GOBAIN

PDS® Products

BN-975 Wafers

Figure 1. Process Cycle for High Temperature BN-975 2-Step H_2 Injection

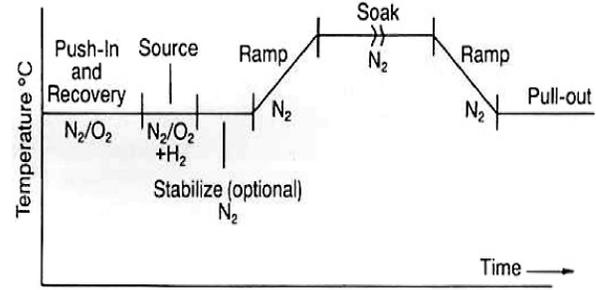*Figure 2. Process Cycle for Low Temperature BN-975 H_2 2-Step Injection*

For Low Temperature Applications: PDS® BN-975* wafers with hydrogen injection also offer flexible applicability that can produce sheet resistivities of more than 2000 Ω/ to less than 10 Ω/. The hydrogen injection process can be used for shallow structures such as bases for high speed high density bipolar devices, MOS sourcedrain and CMOS p-well applications. Similarly, this process can also be used for deep isolation diffusions, bases for power transistors, bases for linear bipolar devices, guard rings, channel stops and other applications.

PROCESS OUTLINE FOR LOW TEMPERATURE BN-975 2-STEP H_2 INJECTION

Step	Ambient	Time	Function
Recovery	N_2/O_2 (50%/50%)	≥15 min.	Thermal Equilibrium Thin Oxide Growth
Source	Add H_2 1-2%, Vol.	1-2 min.	Dopant Glass Transfer
Soak	N_2 (100%)	≥30 min.	Defect Control Resistivity Target
Deglaze	10:1 HF	Variable	Remove Unreduced Boron Glass
Low Temp. Oxidation (LTO)	O_2	≥20 min.	Remove Si-B Layer and Defects

During the recovery step, source boats stacked with BN-975 wafers and silicon wafers are pushed into a diffusion tube. The tube is then allowed to establish ambient equilibrium. This step is generally performed in an ambient of 50% N_2 and 50% O_2 at 750°C-850°C. Typical flow rates are 10 slpm for 150mm wafers, 8 slpm for 125mm wafers, and 6 slpm for 100mm wafers. Note that gas flows depend greatly on closure system design and tube setup.

The N_2/O_2 ambient during the recovery step oxidizes the BN wafers forming B_2O_3 on the surface of the wafer while simultaneously growing a thin layer of SiO2 in the mask window regions. This thin layer of SiO_2 masks B_2O_3 diffusion during the push in cycle, thus minimizing or eliminating the sheet resistivity gradients due to the first wafer in being the last wafer out.

The function of the sourcing step is to rapidly transfer dopant glass from the BN-975 wafer surface to the surface of the silicon wafer. This is accomplished by the controlled injection of up to but no greater than 2% (by volume) H2 gas into the N2O2 diffusion tube ambient which, in turn, keeps the hydrogen under the combustion limit. The introduction of hydrogen into the diffusion tube causes a hydration reaction of B_2O_3 in the HBO_2 (metaboric acid) at essentially the same instant throughout the diffusion tube. The hydrogen gas flow is maintained between 1 min. and 2 min. depending on how much dopant glass is desired. During the sourcing step, an extremely rapid glass transfer occurs due to the higher partial pressure of the HBO_2 species as compared to the pressure of B_2O_3. There is sufficient pressure of HBO_2 to allow transfer as low as 750°C.

A typical hydrogen injection cycle will produce 500-1000 Å of soluble HBO_2 dopant glass with only one min. of H_2 injection and 2% hydrogen. This rapid flux of dopant glass initiates the damage and defect control mechanism.

At the end of the source step, both H_2 and O_2 are shut off. Nitrogen flow is increased to equal the total flow during the recovery step. Gas control panels are available from several manufacturers specifically for the hydrogen injection process. Mass flow controllers are also available that allow for constant flow starts. Constant flow is absolutely imperative in order to avoid the problems associated with "hard" starts (the buildup of pressure in the gas line in which a large amount of gas is shout out initially until the mass flow controller reacts) or "soft" starts (associated with older gas control units that allow only a gradual rise of gas flow that prevents full flow from being reached only during the last few seconds of the one min. H_2 injection cycle, and not the necessary full duration).

Foaming gas (N_2/H_2) may be used as an alternative to the use of H_2 gas. During sourcing, the foaming gas flow should be at a level in which H_2 volume percent is less than 2% of the total flow. Relatedly, nitrogen gas flow must be reduced by the amount of N_2 gas flow contributed by the foaming gas so that the N_2/O_2 ratio during sourcing is the same as it was during recovery. In other words, all levels must be correlative to those present in regulated H_2 use.

Regardless of the method of hydrogen injection chosen, though, it is important that gas flows are accurate and reproducible and that H_2 volume percent levels are below 2% of the total N_2/O_2 ratio.

After sourcing, a 10 min. N_2 purge may be performed to remove latent moisture before the pull step and, in low temperature wafers, establish gaseous equilibrium before ramping (see Figure 3 for partial system pressures).

Figure 3. Partial Pressures of the B_2O_3/ H_2O System
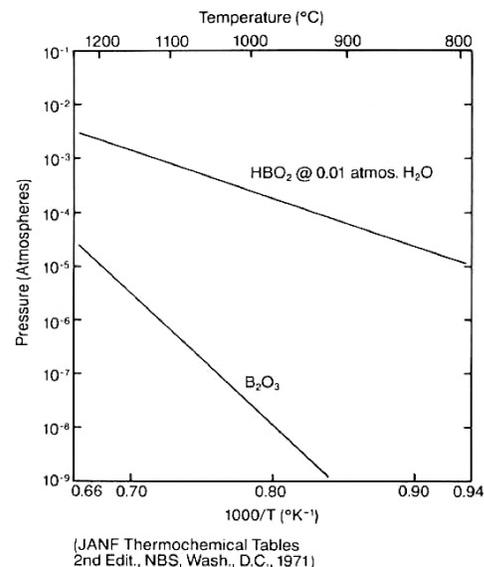
TRANSFER

The transfer step separates the silicon wafers from the BN wafers by transferring the silicon to an oxidation boat for the subsequent high temperature (1000°C+) soak step. The time between when the boat is pulled and when the silicon wafers are pushed into the soak furnace should be kept to less than 30 min. (ideally, less than 20 min.).

By not exposing the BN-975 wafers to higher temperatures, the sources can be expected to have longer lifetimes. Consequently, this type of processing allows increased flexibility as the BN boat may then be used in another deposition process in a different tube while the first silicon lot is undergoing soak. One set of sources can be used for all boron processes, regardless of temperature.

SOAK

During the soak step, the dopant glass which is uniformly coating the silicon wafers undergoes a reduction reaction in the ambient which results in the formation of a thin insoluble layer of silicon-boride, Si-B, at the silicon surface. The Si-B layer serves traps crystal damage at the silicon/ SiB interface through a strong gettering action. In essence, the function of the soak step is to control damage while obtaining the targeted sheet resistivity.

High Temperature Soak Step Initiation: The soak step is initiated by pushing the silicon wafers coated with B2O3 glass into a furnace tube in which the N2 flow rate has been adjusted to a rate equal to that of the combined N2 and O2 flow rates during the previous recovery and sourcing cycles. Once the desired rate has been achieved, ramp to the soak temperature and soak until the desired resistivity is obtained (see Figure 4A).

Figure 4A. Sheet Resistance vs. Soak Time
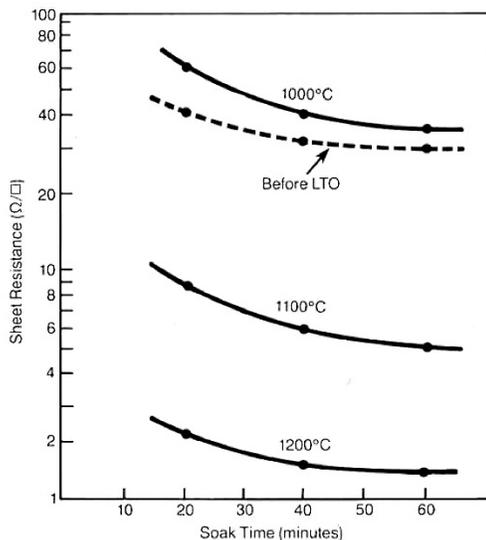
Low Temperature Soak Step Initiation: The soak step is initiated by turning off the H2 and O2 gas flows at the end of the sourcing step, adjusting the N2 flow rate to a rate equal to that of the combined flow rates of the N2 and O2 during the previous recovery and sourcing cycles. Once the desired rate has been achieved, ramp to the soak temperature and soak until the desired resistivity is obtained (see Figure 4B).

*Figure 4B. Sheet Resistance vs. Soak Time*
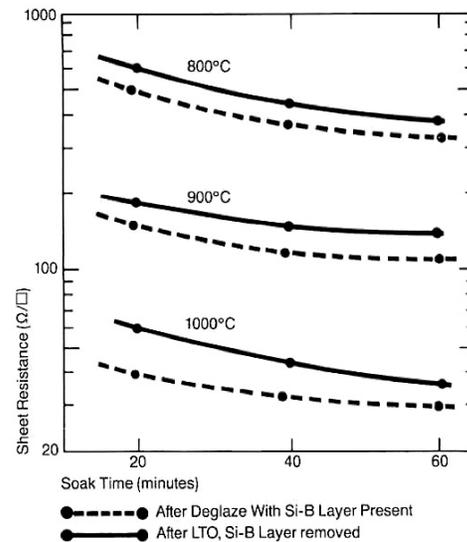
To obtain the best results, it is recommended that the soak cycle be at least 30 min. in length to allow sufficient time for the damage control mechanism to take place and to minimize resistance variation caused by inconsistent pull cycles in furnace unloading. Upon completion of the soak cycle, it is recommended that the furnace be ramped down before pulling the wafers. The use of a controlled environment such as a "white elephant" or a tube extension is beneficial where available as it allows cooling of the wafers under a controlled, moisture- free ambient. This retards the hydration of the unreacted B2O3 which appears as hazing on the surface of the silicon wafers. It is recommended that the time between pulling the wafers and the first deglaze step be less than 30 min.

DEGLAZE
After the Si wafers are unloaded from the furnace, the excess unreached dopant glass is removed by a boron etch, such as 10:1 HF. Many different boron glass etches, even hot water, can be used for this purpose. After deglaze, the silicon surface is hydrophillic (i.e. wets) due to the presence of the unetchable Si-B layer. This layer is typically 200Å thick. At this stage of the process, wetting of the silicon is acceptable as the next stage of treatment will remove the Si-B and some Si along with the defects.

Figure 5.
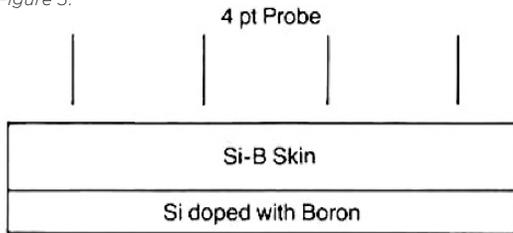
If a four point probe resistivity check is performed at this time, the sheet resistivity measurements will be lower than after the Si-B phase is removed due to the fact that the probe is measuring the lower resistivity of the Si-B layer in parallel with the diffused layer beneath it. Measurements at this time are valid process checks once the amount of resistivity shift is determined by deglazing and probing following the low temperature oxidation while setting up the process.

LOW TEMPERATURE OXIDATION (LTO)

The function of the LTO step is to oxidize the Si-B layer and a thin layer of Si below it. Oxidizing this thin Si layer will immobilize most of the crystal defects in the oxide. A steam or O_2 ambient is typically used to cause the rapid oxidation of the Si-B layer and it's silicon interface region before harmful propagation of the defects into the silicon can occur. This allows the subsequent drive cycle to be damage free.

To determine the optimum LTO cycle, it is necessary to produce a load of wafers through to the first deglaze. The lot is then split and the wafers are put through incremental LTO cycles after which they are checked by one of several methods to determine the required LTO cycle.

A common method to determine the LTO cycle is to measure incremental percent changes in sheet after the deglaze after LTO step. This step, kept during production, is used during process characterization and development to establish the process. If the deglaze step is omitted from production, the subsequent drive should be run in a pure O_2 environment to prevent for formation of unetchable silicon compounds. A "knee" in percent change vs. LTO time curve will correspond to the time required to remove the Si-B phase. It is desirable to oxidize 50-100 angstroms beyond the Si-B phase as this traps the defects in the oxide. Other methods for discerning the LTO cycle, such as deglazing and Sirtl or Wright etching to determine defect density and incremental oxide growth measurements, can be used. Please contact our Engineering Department at if you have questions regarding these procedures.

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