BoronPlus®/PhosPlus®

Product Bulletin 510

Solid Diffusion Sources

(Formerly PB 410 or PB 610)

Insertion, Ramping and Withdrawal Procedures

Introduction

The benefits of using BoronPlus and PhosPlus planar dopant sources in the production of semiconductor devices are well known. To obtain the best results, however, consideration must be given to a number of key processing parameters. One of these parameters is the thermal response of the sources when heated to and cooled from the deposition temperature. This bulletin suggests techniques for insertion, ramping and withdrawal of the dopant sources. Using these suggestions, process engineers should be able to achieve the following:

- Reduce or eliminate source warpage
- Improve sheet resistivity uniformity
- Increase source lifetime
- Reduce thermal gradients across the silicon wafer and across the dopant source
- Increase product yields

Recommended Processing Parameters

Many factors can affect the results of a deposition cycle. Of particular importance is the furnace temperature profile. A very steep temperature gradient normally occurs between the front of the flat zone and the mouth of the diffusion tube. If the carrier is rapidly pushed or pulled through this portion of the diffusion tube, a large temperature gradient will form across the radius of the sources. If this gradient is too high, the stresses that develop can warp or break either the silicon wafer or the dopant source. The gradient can also introduce slip planes in the silicon wafer which usually result in decreased product yields.

To minimize these temperature gradients and to improve the performance of the BoronPlus and PhosPlus sources, the insertion, ramping and withdrawal parameters outlined in Table I are suggested. These parameters should be considered as starting points in the development of the optimum deposition cycle for a given process.

Comments on Processing Parameters

Insertion and Withdrawal Temperatures: The insertion and withdrawal temperatures given in Table I will minimize warpage and are the maximum temperatures that should be used. Lower temperatures are certainly acceptable, however, since they will not harm the sources and they could have other beneficial effects on the silicon (less damage) and final device properties (higher minority carrier lifetime). Generally, the difference between the deposition temperature and the insertion/withdrawal temperature should be greater than 100°C.

Insertion and Withdrawal Rates: The insertion and withdrawal rates given in Table I are the maximum rates that should be used when the temperature gradient in the diffusion tube is about 50°C/inch. If the insertion rate is too fast, breakage of the sources could occur. If the withdrawal rate is too fast, the sources could warp. The withdrawal rate is probably too fast if the center of the source is observed to be red when the boat is exiting from the diffusion tube.

Pulling the boat into an ampule (elephant) is also recommended. The ampule decreases temperature gradients across the sources and the silicon wafers when the boat is out of the furnace, and it minimizes the amount of room air, which often contains various concentrations of particulates, from flowing between the sources and the silicon during cooling.

Many of the modern furnaces exhibit temperature gradients which are much steeper than 50°C/inch. Consequently, slower push/pull rates through the temperature gradient may be necessary to prevent warpage of the sources and to minimize silicon damage. Since these furnaces are usually controlled by microprocessors, the diffusion engineer could consider a program which has a rapid push to the beginning of the temperature gradient, a slow push through the gradient, and then a rapid push into the hot zone.

Stabilization Time: The boatload of sources should be allowed to come to thermal equilibrium at the insertion temperature after reaching the hot zone. This will help to insure that both ends of the boat will reach the deposition temperature at the same time after the furnace ramp has been completed. The result will be an improved doping uniformity across the boat.

The minimum recommended stabilization times given in Table I increase with increasing source diameter because of the greater mass of material which must be heated. The diffusion engineer may find that even longer times are necessary if a large number of sources are used and/or if the furnace recovery time is slow.

Ramp Rate: Most diffusion furnaces are capable of heating at a rate of about 10°C/min. This is an acceptable rate for sources that are 2 or 3 inches in diameter. However, the slower heating rates given in Table I are recommended for the larger diameter sources to insure uniform heating across their diameters. If temperature gradients are too great, silicon damage and nonuniform doping can occur along the outside edge.

If controlled heating and cooling rates are not available, uncontrolled rates are usually acceptable. In this case, however, the two end zones must be slave-controlled to the center zone. If they are not slave-controlled, non-uniform heating of the boat may occur resulting in non-uniform doping across the boat.

Deposition Time: Sufficient time must be allowed at the deposition temperature for a solid source system to reach thermal equilibrium and for the sources to deposit enough B_2O_3 to uniformly dope the surfaces of the silicon wafers. The minimum time that is required to give good results increases with increasing source diameter. Experience has shown that times less than those given in Table I are generally too short to obtain acceptable uniformities.

Comments on Direct Insertion

Some users may choose to insert their diffusion carrier directly into the furnace at the deposition temperature. Direct insertion is not generally recommended for any size source. Process engineers who choose to use direct insertion may observe premature warpage of the sources and nonuniform doping of the silicon, especially across the boat.

If the direct insertion technique is selected, however, the diffusion engineer may find it necessary to tilt the furnace temperature profile to compensate for the longer time at temperature for sources and silicon at the gas inlet end (source end) of the boat (first-in last-out effect). An alternate technique to direct insertion into the hot zone that sometimes works for 2 and 3 inch diameter systems is to quickly push the diffusion carrier through the hot zone, allow the silicon and sources to stabilize near the gas inlet end of the tube, and then pull the boat slowly back into the hot zone. At the end of the deposition time, the boat is then slowly pulled back to the front of the tube from the hot zone. Since this technique makes the first-in end of the boat also the first-out end, variations across the boat are minimized.

For more information on this Product Bulletin or on the BoronPlus and PhosPlus dopant sources, contact the Planar Dopants Team: www.techneglas.com

Table I. Recommended Processing Parameters

Source Type	Source Size	Part No.	Insert/Withdrawal Temp	Insert/Withdrawal Rate	Stabilize Time	Ramp Rate	Min Dep Time
BoronPlus							
GS126	2 X .060”	9321	850°C	8 in/min	3 min	10°C/min	30 min
	3 X .060”	9330	800	4	5	10	30
	100 X 2.0mm	9341A	800	4	8	7	45
	125 X 2.5mm	9352A	750	3	12	5	60
	150 X 3.0mm	9363A	700	2.5	15	3	60
GS139	2 X .060”	9021	950	8	3	10	30
	3 X .060”	9030	900	4	5	10	30
	100 X 2.0mm	9041A	850	4	8	7	45
	125 X 2.5mm	9052A	750	3	12	5	60
	150 X 3.0mm	9063A	700	2.5	15	3	60
GS183	2 X .060”	9121	950	8	3	10	30
	3 X .060”	9130	900	4	5	10	30
	100 X 2.0mm	9141A	850	4	8	7	45
	125 X 2.5mm	9152A	750	3	12	5	60
	150 X 3.0mm	9163A	700	2.5	15	3	60
GS245	2 X .060”	9221	950	8	3	10	30
	3 X .060”	9230	900	4	5	10	30
	100 X 2.0mm	9241A	850	4	8	7	45
	125 X 2.5mm	9252A	750	3	12	5	60
	150 X 3.0mm	9263A	650	2.5	15	3	60
GS278	2 X .060”	9421	950	8	3	10	30
	3 X .060”	9430	900	4	5	10	30
	100 X 2.0mm	9441A	850	4	8	7	45
	125 X 2.5mm	9452A	750	3	12	5	60
	150 X 3.0mm	9463A	650	2.5	15	3	60

Source Type	Source Size	Part No.	Insert/Withdrawal		Stabilize Time	Ramp Rate	Min Dep Time
			Temp	Rate			
PhosPlus							
TP250	2 X .060"	7221	750°C	8 in/min	3 min	10°C/min	30 min
	3 X .060”	7230	750	4	5	10	45
	100 X 2.0mm	7241A	750	4	8	7	45
	125 X 2.5mm	7252A	700	3	12	5	60
	150 X 3.0mm	7263A	700	2.5	15	3	60
TP470	2 X .060”	7321	950	8	3	10	30
	3 X .060”	7330	850	4	5	10	45
	100 X 2.0mm	7341A	800	4	8	7	45
	125 X 2.5mm	7352A	750	3	12	5	60
	150 X 3.0mm	7363A	700	2.5	15	3	60