BoronPlus®/PhosPlus®

Product Bulletin 514

Solid Diffusion Sources

(Formerly PB 414 or PB 614)

Storage Techniques

Introduction

In typical semiconductor operations, the best results will usually be obtained when water vapor in the diffusion tube is carefully controlled and kept to a minimum. Trace amounts of water vapor can cause silicon surface damage, non-uniform doping of the silicon slices, increased boron penetration into the field oxide, and other yield reducing effects. This bulletin discusses storage techniques that will minimize the amount of moisture from entering the diffusion tube that originates from diffusion equipment and materials.

Sources of Water Vapor

Water vapor can originate from a variety of sources. Excluding gross equipment malfunctions such as cracked diffusion tubes and air leaks in the gas lines, small but significant amounts of water vapor can enter the diffusion tube through various routine processing operations. Those most often identified are:

- Incomplete drying of the silicon slices.
- Trapped air between the silicon slices and planar diffusion sources.
- Air back-streaming down the diffusion tube during insertion of the boat.
- Moisture as an impurity in the carrier gas.
- Absorption of moisture from the atmosphere by the diffusion boats, paddles, etc. during the loading/unloading steps.

When diffusion boats have been used for a large number of runs, they begin to accumulate a thin B_2O_3 or P_2O_5 glassy film. Proper storage techniques must be used to prevent this film from absorbing significant amounts of moisture. When the film becomes thick enough, however, it also becomes more hygroscopic and begins to absorb water vapor from the air during the silicon wafer loading/unloading operation. At this time the sources should be removed from the boat, and the boat should be cleaned with a light HF etch. The boat cleaning can be done as often as desired when BoronPlus and PhosPlus sources are used since they do not stick to the diffusion boats.

The dopant source itself can also be a source of moisture if not properly stored while not in use. There is a significant difference in the amount of moisture the two types of boron planar diffusion sources available to the industry will absorb when left exposed to ambient air. The boron nitride source contains a thin surface layer of B_2O_3 which is extremely hygroscopic and will rapidly absorb moisture from the atmosphere, even during the relatively short time involved in the silicon loading/unloading operations. The BoronPlus source, however, has most of the B_2O_3 stored within the bulk of the material and not on its surface. This results in significantly less moisture absorption from the atmosphere. Tests conducted on BoronPlus and boron nitride sources have shown that boron nitride wafers can increase in weight by as much as 1.1% [1] while BoronPlus sources increased less than 0.02% when stored under similar conditions.

Since the phosphorus is present within the PhosPlus sources in the form of a complex crystal and not as the extremely hygroscopic P_2O_5 material, the PhosPlus sources exhibit a minimum amount of water absorption. However, the sources can absorb small amounts of moisture which may affect the electrical properties of certain devices such as high betas from the phosphorus emitter diffusion of a bipolar transistor. It is therefore recommended that the sources be stored in the diffusion boats in a dry environment at an elevated temperature when the time between runs exceeds about 45 minutes.

If either the BoronPlus or PhosPlus sources were accidentally left out in a room for a long period of time, they can be quickly prepared for the next run by merely inserting them into the diffusion tube at the insertion temperature for about 15 minutes. When they are withdrawn from the tube, the boat is ready for loading with production silicon.

The solid sources and the diffusion boat should not be allowed to absorb small amounts of moisture during long term storage if optimum results are to be obtained. The following discussion will therefore provide the process engineer with several alternate storage techniques from which to choose. He should select the technique that best suits his diffusion process and the one that is compatible with his available storage equipment.

Alternate Storage Techniques

Selection of the best method for storing BoronPlus or PhosPlus sources when not in use depends to a large extent on the sensitivity of the process to the presence of water vapor. Generally, the base diffusions in bipolar processes and the source/drain diffusions in MOS processes require the greatest control of moisture. Less sensitive processes include certain isolation diffusions and high temperature etch stop applications.

For the most critical processes:

a) Store in the hot zone of the furnace after it has been turned down to about 600°C. This technique is highly recommended for optimum results. It has been found to be very effective for applications that are extremely sensitive to minute traces of water vapor.

For processes that are moderately sensitive to moisture:

b) Store at the mouth of the diffusion tube with hot nitrogen gas from the diffusion tube passing over the boat. The gas flow rate should be kept high enough to prevent air from back-streaming into the diffusion tube through any holes in the end cap. Care should be taken to be certain that the gas inlet (source) end of the boat does not extend into the hot zone of the diffusion tube. If the cool zone at the front of the diffusion tube is too short for the length of the diffusion boat, the furnace tube can be extended by the use of an "elephant".

c) Store in a dry box being held at 200°C or higher and continuously purged with dry nitrogen. This technique is commonly used by many companies as an alternative to technique b).

For processes that have little sensitivity to moisture:

d) Store in an extension of a diffusion tube or "elephant" that is capped and continuously purged with dry nitrogen at room temperature. This technique is normally considered to be the minimum care that one should take when storing a diffusion boat and sources.

e) Store the sources in a laminar-flow clean hood. Although this technique will keep the boat and sources clean, they will be continuously exposed to any moisture that is present in the room air. If this storage technique is selected, the process engineer should evaluate his product very carefully to insure that this method will not have adverse effects upon it.

Conclusion

The storage technique that is selected for a particular process must be determined by the process engineer. Experience has shown that careful consideration and selection of an appropriate storage procedure is a vital element in the successful application of planar sources to semiconductor fabrication.

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

References:
1. David Rupprecht and Joseph Stach, "Oxidized Boron Nitride Wafers as an In-Situ Boron Dopant for Silicon Diffusions", J. Electrochem Soc., Vol. 120, No. 9, Sept. 1973, pp. 1266-1271.