TECHNEGLAS® TECHNICAL PRODUCTS

BoronPlus®

Product Bulletin 320

Solid Diffusion Sources

Etch Stop Application for BoronPlus Sources

Introduction

Sensors and miniature devices made from silicon wafers have been the subject of intense research by many companies and certain universities during the last several years. Thin membranes for pressure sensors, cantilever beams for acceleration sensors, bridges for measuring fluid flow rates, small holes for sieves, various parts for miniature motors, etc. are already being fabricated for assembling into devices for a number of industrial applications [1-15].

By utilizing standard silicon processing techniques, areas of high boron concentration can be carefully located within the silicon wafer by diffusion. These areas act as "etch stops" for different silicon etchants [16,17] and are critical to successfully etching thin membranes and various micromechanical parts from the silicon wafer.

Many researchers have used BoronPlus dopant sources to dope the silicon with boron to create the etch stop for the silicon etchants [18-22]. The BoronPlus sources are a highly desirable source for boron because they are safe and easy to use, and because they provide sufficient boron to create the desired etch stop in the silicon wafers. The sources can also be used in the presence of oxygen permitting the boron silicon phase that forms on the surface of the silicon wafer to be oxidized while cooling in oxygen from the deposition temperature (in-situ LTO). This bulletin summarizes some of the procedures that have been developed over the years for using BoronPlus sources in the etch stop application.

Typical Deposition Cycle

Table 1 outlines a typical deposition cycle for an etch stop diffusion. Several of the basic parameters that must be taken into consideration when designing one of these processes are:

1. Deposition Temperature and Time

The deposition temperature usually ranges between 1100° and 1200°C for the following reasons:

a) The boron in the silicon must be greater than about 1E20 atoms/cc to stop the anisotropic etchants, and

b) The boron concentration of 1E20 must be maintained from the surface to several microns below the silicon surface.

The high deposition temperature results in the formation of the desired boron concentration in the silicon wafer, and it causes the deposited boron to diffuse into the silicon wafer from its surface at a relatively high rate.

Figure 1 shows the relationship between the depth where the boron concentration is about 1E20 (etch stop layer) [21,23] and the diffusion time at various temperatures to reach this depth. Although these data can be used to quite accurately predict the thickness of large-area diffused membranes, other factors can have significant effects upon the shape and dimensions of certain intricate substrates being etched from silicon [8,17,24]. These factors include the lateral diffusion of boron in silicon, the thickness of the desired substrate, and the dimensions of the diffusion window in the field oxide.

If the silicon sensor is to contain an active device area, the area on the silicon wafer must be defined before the etch stop diffusion is performed. Procedures to isolate these active areas and to incorporate MOS devices on them have been developed and have been successfully used to make devices [8].

Table 1. Typical Etch Stop Diffusion Cycle

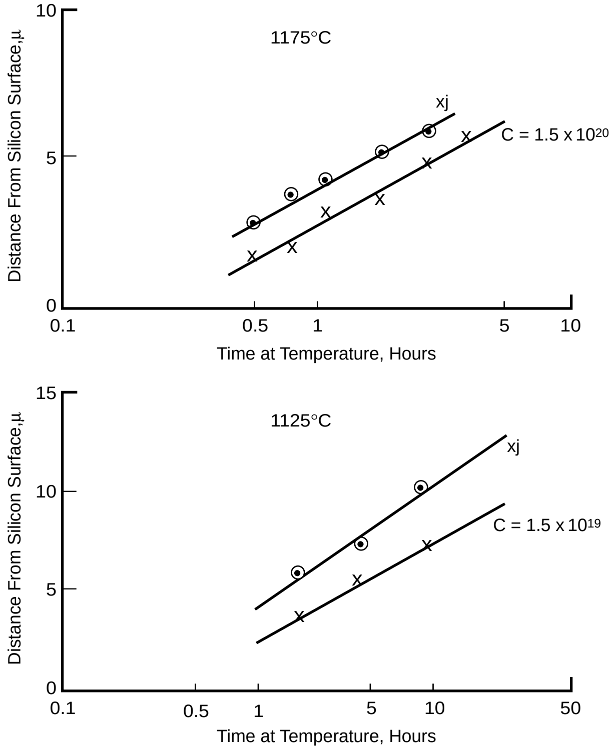
Source Type:	Source Size:	Source Diameter
GS-245 (9241A)	100 x 2.0mm	150mm

Dep

Step	Rate/ Time	Temp.	Gas	Flow Rate
Insert	4”/Minute	800°C	N_2 + 2% O_2	5 l/min.
Stabilize	10 Minutes	800°C	N_2 + 2% O_2	5 l/min.
Ramp	7°C/Minute	1125°C	N_2 + 2% O_2	5 l/min.
Hold	8 Hours	1125°C	N_2 + 2% O_2	5 l/min.
Ramp	7°C/Minute	800°C	N_2 + 50% O_2	5 l/min.
Pull	4”/Minute	RT	N_2 + 50% O_2	5 l/min.

Figure 1

Etch Stop Diffusions From BoronPlus Sources [21, 23]



2. Insertion Temperature and Ramp Rates

A ramp rate of 5-10°C/min from and to the insertion temperature of about 850°C is acceptable for most etch stop diffusions. It has been reported, however, that ramp rates of less than 5°C/min from and to insertion temperatures that are as low as 500°C help to minimize source warpage and to keep silicon warpage to less than 10 microns.

3. Gas Composition

The gas used in the boron deposition cycle can be either nitrogen or argon. Although it has been reported that argon produces silicon surfaces which visually exhibit the least amount of damage [23], it is possible to control surface damage with either gas by utilizing a small amount of oxygen. The oxygen is typically in the range of 2-5%, but as much as 10% has been used for long depositions at high temperatures.

It is a common practice to cool the silicon wafers in a 50% mixture of oxygen and nitrogen or argon [21,23]. The oxygen diffuses through the deposited glassy film and oxidizes the boron-silicon phase that forms on the silicon surface under the film. Residual stresses causing deflections of cantilever beams and buckling of membranes can be controlled by the proper use of this in-situ low temperature oxidation (LTO) cycle. [25,26]

An alternate method of removing the boron silicon phase is to use the conventional low temperature oxidation cycle (LTO) [27]. The first step of the LTO cycle is to etch the deposited glass from the silicon wafer in dilute HF. The silicon wafers are then placed back in the diffusion furnace near 850°C without the sources being present and are oxidized in steam for a sufficient amount of time to oxidize the entire boron-silicon phase. Oxidation of the silicon can be continued to form a field oxide, or the silicon wafers can be removed from the diffusion furnace and re-etched in dilute HF to remove the thin glassy film. The HF etch produces a clean, hydrophobic silicon surface that is ideal for further silicon processing.

4. Diffusion Boats

The standard quartz diffusion boats described in Product Bulletin 515 have been routinely used in boron etch stop diffusions. However, quartz boats usually do not hold up well at the high temperatures that are required for etch stop diffusions and tend to warp, crack and sometimes break. Although silicon carbide and polysilicon boats are more expensive than quartz, it has been reported that they do hold up much better at these high deposition temperatures.

Anisotropic Etchants

Silicon wafers that are lightly-doped with boron can be rapidly etched in the <100> and <110> direction with the anisotropic etchants KOH, EDP (ethylenediamine/pyrocatechol/water) and hydrazine [16,18]. The <111> direction in silicon is etched very little by these etchants, and the etching of the silicon in all directions essentially stops when the boron concentration in the silicon exceeds about 1E20.

The positive and negative attributes of each of these anisotropic etchants are discussed in the literature [8,16-18]. Various factors such as safety, silicon dioxide etch rate, silicon etch rate, etc., will determine which etchant is best suited for a particular application.

Sensor Packaging

Procedures have been developed [28] for sealing two silicon wafers together for the purpose of enclosing the sensor circuitry while leaving the sensor membrane exposed to interact with the ambient. The technique utilizes the GS139 BoronPlus sources to deposit a thick boron glassy film on one of the silicon wafers at 1075°C using the procedures outlined in Table 2. This film acts as a "glue" which produces a strong seal between two silicon wafers when they are placed in contact with each other and are heated to temperatures as low as 450°C.

Table 2. Boron-Glass Bonding Procedure (28)

Source Type	Source Size	Source Diameter
GS-139 (9041A)	100 x 2.0mm	150mm
Source Preparation:	1075°C for 60 hrs. N_2 = 2.5 l/min. O_2 = 2.5 cc/min. N_2 + 10% H_2 = 5 cc/min. 600°C for 16 hrs. N_2 = 2.5 l/min.	

Step	Rate/ Time	Temp.	Gas	Flow Rate
Insert	2.5”/Minute	800°C	N_2	1 l/min.
Stabilize	15 Minutes	800°C	N_2	1 l/min.
Ramp	4.5°C/Minute	1075°C	N_2	2.5 l/min.
Hold	60 Minutes	1075°C	N_2 +2.5 cc/Min. O_2 +5 cc/Min. Forming Gas (90%N_2 +10% H_2)	2.5 l/min.
Ramp	10°C/Minute	800°C	N_2	2.5 l/min.
Pull	2.5”/Minute	RT	N_2	2.5 l/min.

To achieve wafer bonding at 450°C, the surfaces must be phosphorus-free and free of particulate matter.
If phosphorus is in the system, the bonding must be made at temperatures near 900°C. The silicon wafers should either be stored near 600°C in nitrogen until they are ready to be used, or bonding should be done immediately following the glass deposition cycle. Additional details of the bonding procedure are available in the literature. [29,30].

Conclusions

The manufacture of many sensors and miniature devices from silicon requires the use of a boron etch stop layer to selectively stop the anisotropic etching of silicon at the appropriate place. Tests have shown that the BoronPlus sources are an excellent source for creating these layers within the silicon wafers. Procedures have also been developed to use BoronPlus sources in a process that seals two silicon wafers together at low temperatures.

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