

BORON SOLID SOURCE CHARACTERIZATION

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ABSTRACT

Standard Oil's BN-975 planar diffusion sources were used to fabricate integrated resistors. Dopant transfer was done in a $N_2:O_2:H_2$ ambient at 975 C. Two methods of removing the crystal defect layer formed at the surface, low temperature oxidation (LTO) and a nitric acid soak, were evaluated. Successful layer removal was achieved with the LTO. The nitric acid soak met with limited success.

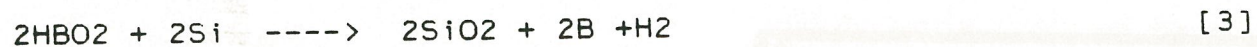
INTRODUCTION

Boron nitride wafers can be used as diffusion sources for p-n junctions. This method of diffusion alleviates the uniformity and repeatability problems associated with spin-on sources and gases. It is also a much safer alternative to the carrier gas system in which the dopants are found in toxic, poisonous and corrosive liquids and gases. Ion implantation, a fourth method of impurity doping, is limited by low throughput. Planar source processing also results in fewer defects in the p regions which leads to increases in carrier lifetime and current gain and a reduction of leakage current [1].

When boron nitride is used as a diffusion source, it is mixed with silicon dioxide and formed into thin wafers. These wafers are approximately the same diameter as the wafers to be diffused. The amount of silicon dioxide used depends on the desired temperature range. Lower temperature ranges require less silicon dioxide [2]. Prior to use as dopant sources, the source wafers must first be oxidized or activated. This oxidation converts some of the boron nitride to boric oxide (B₂O₃). The boric oxide is transferred from the source wafers to the device wafers and serves as the source of boron for the diffusion. Once activated, the sources are good for 300 hours of use. Between runs, they must be stored at 400 C in dry N₂. Prior to runs, they must be stabilized for thirty minutes at 800 C in dry N₂.

Transfer of dopant occurs during the sourcing step which is done during a controlled injection of up to four volume percent H₂ gas into N₂ and O₂ diffusion tube ambient. This is known as the hydrogen injection process. Typically, the sourcing step is only one to two minutes long since the B₂O₃ dopant glass is

almost instantly converted to boric acid (HBO_2) [4]. Due to the higher vapor pressure of HBO_2 compared to B_2O_3 , the dopant is transferred to the silicon surface of the target wafer [1]. Chemical reactions for source oxidation and target deposition are shown below [2,3].



The HBO_2 glass that is deposited on the target wafers must be reduced in a nitrogen ambient. Excessive amounts of HBO_2 can lead to greater field oxide penetration. Furthermore, sticky build-ups can occur on the quartz boat and inside the diffusion tube. The HBO_2 glass is reduced during a dry nitrogen soak step. As a result of the soak step, a thin insoluble layer of silicon boride, SiB , is formed at the silicon surface. At this point, the boron has been diffused into the silicon and the crystal damage has been trapped in the SiB/Si interface [5].

The SiB layer must be removed by oxidation. A thin layer of silicon below the SiB layer is also oxidized and removed. Consequently, the defects trapped in the SiB layer are also removed. Oxidation can be accomplished by a low temperature oxidation. Typically, LTO's are done at temperatures between 700-800 C for times of ten to thirty minutes [1]. A nitric acid soak done at 90 C for 30 minutes will also oxidize the SiB surface [5].

The wafers can be four point probed prior to the LTO growth. The resistance that is measured is the resistance of the SiB layer in parallel with the diffused layer below it [5]. A four point probe performed after the LTO will yield the true sheet resistance of the diffused layer.

This project involved the activation of the BN-975 planar sources and the use of them to deposit boron on device wafers. Specifically, the problem of removing the SiB layer that is created during the diffusion process was addressed. Two methods for removing this layer were compared and evaluated.

EXPERIMENT

A masking oxide of 3000-4000Å was grown on three inch n-type {100} silicon wafers with resistivities of 7.5-12.5 Ω -cm. The wafers were coated with KTI-820 photoresist and exposed using a mask which allowed one half of each wafer to be completely diffused with boron and the other half to be patterned with diffused resistors, as shown in Figures 1 and 2.

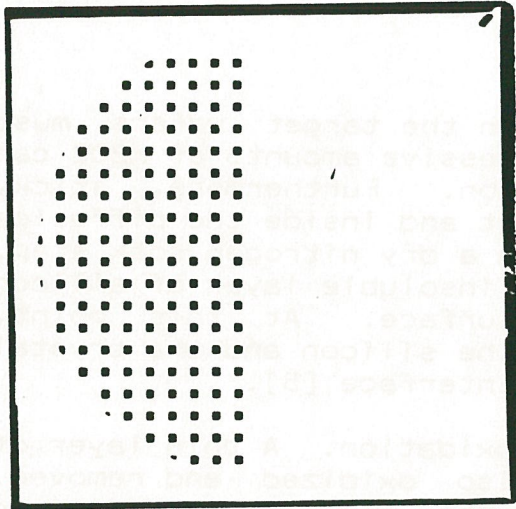


Figure 1: Mask Pattern

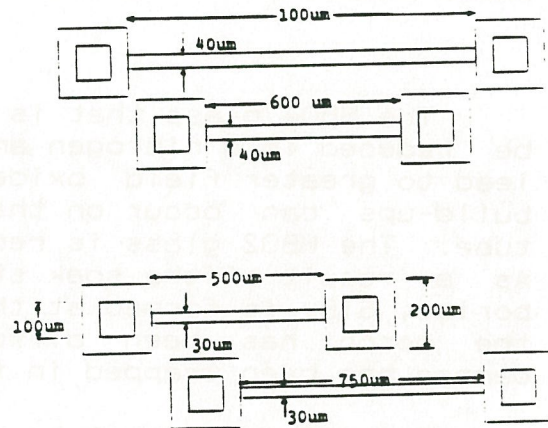


Figure 2: Device Pattern

The completely diffused half of each wafer provided areas for four point probe measurements and for ellipsometer measurements immediately following the planar source diffusion. After development, the silicon wafers were diffused at a temperature of 975 C for three different soak times of 15, 30 and 45 minutes.

The wafers were deglazed in 10:1 hydrofluoric acid for two to three minutes. The wafers then underwent either a LTO for 10, 20 or 30 minutes and an HF etch (18 wafers) or they were soaked for 30 minutes in nitric acid at 90 C (6 wafers). Four point probe measurements were taken prior to the masking oxide growth, after the deglazing and after the LTO or the nitric acid soak. Ellipsometer measurements were taken prior to and after the LTO. Junction depths were measured after the removal of the Si-B layer using the groove and stain technique.

RESULTS/DISCUSSION

For each diffusion time, four point probe measurements were taken prior to the SiB layer removal and after oxidation. Results of sheet resistance as a function of diffusion time can be seen in Figures 3 and 4. These graphs show three sigma variance and the uniformity of the deposition is evident.

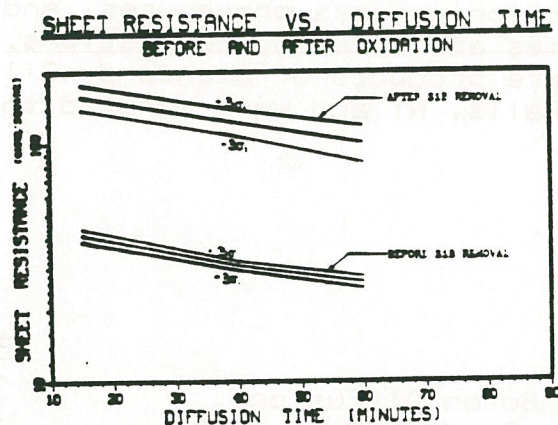


Figure 3: LTO

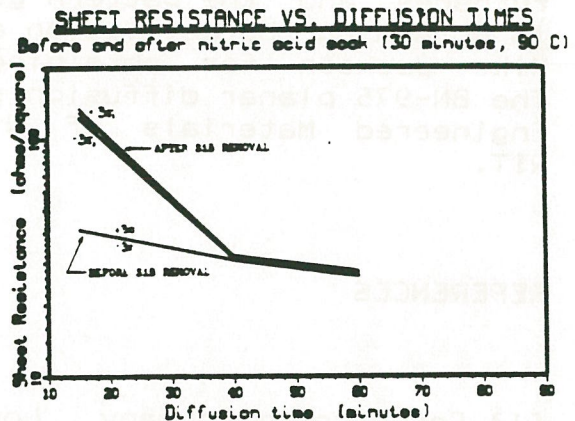


Figure 4: Nitric Acid Soak

Successful SiB removal for all three diffusion times was achieved with the LTO method. SiB removal is indicated by the rise in the measured sheet resistance after the HF etch. The ten minute LTO yielded the shortest HF etch time, but the SiB layer was not completely removed. Additional oxide had to be grown in order to completely oxidize the layer. The thirty minute LTO yielded the best initial results.

The nitric acid soak met with limited success, since only the SiB layer created during the shortest diffusion time was removed during the nitric acid soak. Additional soaking up to thirty minutes did not remove any significant amount of the SiB layer. The soak was discontinued at this point since it had failed to be an effective oxidation method. However, with additional work, a variation of the nitric acid soak may yield successful results. A higher soak temperature or a nitric acid soak followed by an HF etch may remove the SiB layer.

CONCLUSIONS

A preliminary process for boron diffusion and SiB removal for the BN-975 planar sources was achieved. The LTO method yielded the best results. However, preliminary data indicates that the nitric acid soak may work under certain conditions.

ACKNOWLEDGEMENTS

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