DESIGN, CONSTRUCTION, AND QUALIFICATION OF A CHLORINATED OXIDE GROWTH PROCESS

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ABSTRACT

This project dealt with the design and installation of a TCA bubbler system. Considerations for safety and temperature control of the TCA were simplified by the use of a J.C. Schumacher Flow Temperature Control unit. Installation of the system is complete and chlorinated oxides have been grown.

INTRODUCTION

Wet and dry oxide growth techniques are widely used in semiconductor fabrication. However, there are times when it is desirable to reduce sodium ion contamination and enhance the electrical characteristics of the oxide. This is most commonly done when the oxide is being used as a gate oxide in MOS devices. For this reason, oxidation of silicon in a chlorine-containing ambient can be a very beneficial process step. It is possible to reduce the mobile charges in the oxide by two orders of magnitude, increase the minority carrier lifetime by two orders of magnitude and also grow an oxide with much better integrity thus greatly improving the electrical properties. These benefits are not without some drawbacks to the process. These include increased surface roughness of the oxide, the separation of the oxide from the silicon, the etching of the silicon at the Si/SiO2 interface and the increased radiation sensitivity of devices containing chlorine.[1]

Sodium passivation is the process of immobilizing sodium ions in the gate oxide. Sodium passivation can be achieved with the incorporation of chlorine into the oxidation process two ways. The first is a cleaning of the tube itself. There is a very large potential for sodium contamination in the furnace because at elevated temperatures, sodium can diffuse through the walls of the tube. To decrease the contribution of this, it is necessary to perform a cleaning of the furnace tube, boats, and paddle to remove sodium and other metal ion contaminants. A standard procedure is to clean for 45 minutes at a temperature approximately 100 degrees celsius over standard process temperature in a chlorine ambient. It is possible to decrease the contamination levels even more by increasing the cleaning time. The mobile sodium ions in the oxide are also reduced when chlorine is incorporated into the oxide growth process itself. High temperatures are required for passivation to occur. However, some passivation is seen at temperatures as low as 900

degrees celsius. For a particular oxidation time and temperature, the amount of passivation is dependent upon the level of chlorine contained in the oxide. The sodium concentration decreases with increasing chlorine concentrations.[2]

The mechanism proposed for the removal of mobile ion contamination is as follows:particles are present on the silicon surface at the start of oxidation. As the oxide is grown, these particles interact causing defects and they are incorporated into the oxide layer. These particles are usually metallic in nature. If the particles are incorporated into the oxide they become sites for breakdown. During oxidation the chlorine combines with the metallic particles to form metal chlorides which are volatile and are desorbed into the gas stream. The sodium is neutralized by the chlorine through the formation of neutral species. Experiments have shown that 1% TCA is the optimum concentration for passivation and increased dielectric strength. At concentrations lower than 1%, not enough chlorine is present. As the concentration exceeds 1%, corrosion of the silicon surface begins to occur.[3]

Localized impurities in the oxide are also causes of low integrity oxides. These impurities are usually sodium. The mechanism of neutralization is not well understood. It is proposed that the mobile ions become trapped when they reach the vicinity of the chlorine, incorporated in a Si-O-Cl bond where chlorine is substitutional for oxygen. Therefore, the trapping and neutralization of sodium ions occurs only at the Si/SiO2 interface.

EXPERIMENTAL

The gathering of the bubbler and needed hardware was made relatively simple by J.C.Schumacher Company. Upon calling the company for technical assistance, they decided to donate a complete TCA bubbler system to R.I.T. This system contained all safety valves and mass flow controllers needed for installation. Included with the system was the microprocessor control unit which contains mass flow controllers for the oxygen and nitrogen, an oxygen sensor and solenoids in the nitrogen lines to shut the system down in case of a decrease in oxygen, and temperature sensors to control the temperature of the TCA. Also included in the system was the bubbler housing which holds a 500 ml bubbler and heats the TCA.

The design considerations were based on what the tube would be used for, who would be using it, and safety considerations. As a gate oxide furnace, it was decided that it should have the capability of growing chlorinated oxides, dry oxides, and it should also be equipped with a nitrogen purge for post-oxidation anneals. Since many students would be using the furnace, the system should also be fairly easy to operate. Lastly, since chlorine is a harmful gas and that TCA breaks down in the tube to

form HCL, a good exhaust system must be placed at the end of the tube.

RESULTS

The TCA bubbler system is installed and running. A schematic of the system is given in figure 1. The system works by bubbling nitrogen through the liquid TCA, which is regulated at 25 degrees celsius. Oxygen is mixed with the nitrogen/TCA at the tube. Flow rates of the gases are regulated by the Flow Temperature Controller (FTC). This unit also contains all oxygen sensors and solenoids to shut the system down in case of a lack of oxygen. A nitrogen purge can also be performed if the FTC is put into standby. To do this, a switch was installed which puts the unit in standby and allows the electric valve to be switched to nitrogen. With the FTC in run mode, the electric valve can only be placed in the oxygen position. The tube has been cleaned with the TCA and oxides grown with the system show an improvement in mobile ion contamination over those grown with dry oxygen only.

CONCLUSION

The TCA bubbler system has been installed and is working as it was designed to. Mobile ions in the oxides have shown improvement, which should make it possible to fabricate better devices here at R.I.T.

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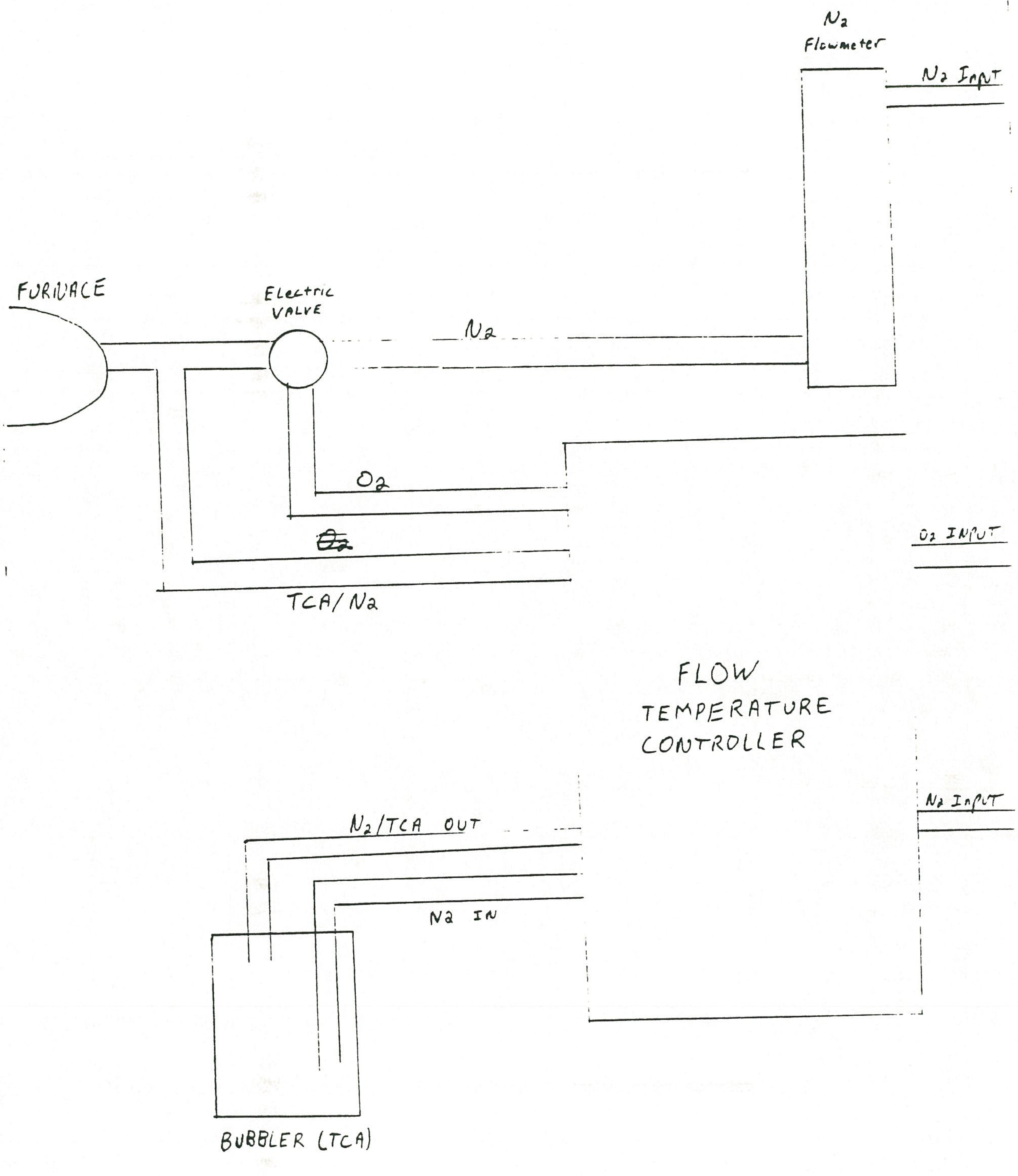

Figure 1. Schematic of TCA bubbler system