

# Development of Process Monitoring Strategies for Contamination Control Utilizing a Surface Charge Analyzer

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**Abstract** - The study done was to develop strategies that utilize the measurement and analytical capabilities of a Semitest Surface Charge Analyzer (SCA 2000) and monitor contamination caused during certain processes and in furnaces in an IC fab. A significant drop in average minority carrier lifetime and an increase in fixed oxide charge was observed. Counterdoping was also observed in one of the furnaces.

## I. INTRODUCTION

A Surface Charge Analyzer monitors oxide quality by determining parameters like Oxide charge, interface trap charge, minority carrier lifetime, and substrate doping. It works by shining modulated light to the semiconductor, as opposed to using 1 MHz ac voltage and it measures the resultant induced charge which is proportional to the depletion region width in the Silicon. The parameters the SCA measures have been shown to change when there is a change in the manufacturing process or there is chemical contamination. In this work, device quality wafers were oxidized and then mapped on the SCA to get baseline values. After that, they were inserted in the furnace tube at high temperature N<sub>2</sub> ambient and remapped. Hence, by monitoring and comparing these values and graphs, and doing some analysis on them, we can detect the presence of contamination and their levels.

## II. EXPERIMENT AND RESULTS

In this study, 3 device quality wafers were used for monitoring three furnaces - a furnace used to grow gate oxide(12), furnace used to anneal ZnO films(16), and a furnace used to do wet oxidation and n type doping(13). The wafers were RCA cleaned using general particu-lo chemicals and the quartz boat used to hold them was immersed for 5 minutes in 100:1 HF to remove

contaminants. TCA clean of furnace 12 was done and 320A of oxide was grown on all 3 wafers in this furnace. The wafers were then mapped using the SCA to establish baseline values. After that, wafer G6 was annealed in furnace 12 for a total of 6 hours 5.5 lpm N<sub>2</sub> at 1000C in increments of 2 hours and it was mapped with the SCA and oxide thickness measured after every 2 hours. Wafer G4 was annealed in furnace 16 for a total of 6 hours 3.5 lpm N<sub>2</sub> at 1000C in increments of 2 hours and mapped with the SCA and oxide thickness measured after every 2 hours. Wafer G5 was annealed in furnace 13 for a total of 2 hours at 1100C and mapped with the SCA and oxide thickness measured.

Expectedly, the average minority carrier lifetime declined 45.51% from 256.2  $\mu$ sec to 139.6  $\mu$ sec (Figure 1) after a total of 6 hours N<sub>2</sub> anneal in furnace 16. This decline in lifetime indicates the presence of metallic impurities in the furnace. i.e. Zinc. Zinc has a high diffusivity of 0.1cm<sup>2</sup>/sec, a high vapor pressure i.e. it outgasses at 900C at atmospheric pressure and at our operating temperature of 1000C it definitely has outgassed from the inside of the tube, and a deep level/mid gap trap of 0.55eV which means it has equal probability of recombination and generation. All this leads to the conclusion that Zinc is the major constituent of the metallic impurity in furnace 16. The average fixed oxide charge increased 45.7% from 3.2e11/cm<sup>2</sup> to 5.9e11/cm<sup>2</sup> after a total of 6 hours N<sub>2</sub> anneal in furnace 16 (Figure 2). This indicated the presence of ions. Another reason for the increase in the fixed oxide charge might be the presence of oxygen in the furnace during the anneal that resulted in the increase of the oxide thickness by 11.7% from a starting value of 313A to 352A after a 6 hour N<sub>2</sub> anneal. The average substrate doping in this furnace stayed stable (Figure 3).

Unexpectedly, the average lifetime declined 30.9% from 266.6  $\mu$ sec to 184.2  $\mu$ sec after a total of 6 hours N<sub>2</sub>



anneal in furnace 12 (Figure 1). This indicates presence of metallic impurities in the furnace. The average oxide charge increased 13.36% from  $3.5e11/cm^2$  to  $4.04e11/cm^2$  after a total of 6 hours  $N_2$  anneal in furnace 12 indicating the presence of ions (Figure 2). Another reason for the increase in the average fixed oxide charge, as earlier, might be the presence of oxygen in the furnace during the anneal that resulted in the increase of the oxide thickness by 11% from a starting value of 325A to 365A after a 6 hour  $N_2$  anneal. Average substrate doping stayed stable in this furnace (Figure 3).

Quite expectedly, the average lifetime declined 37.2% from 82.08  $\mu sec$  to 51.54  $\mu sec$  after a total of 2 hours  $N_2$  anneal in furnace 13 indicating the presence of metallic impurities in the furnace (Figure 1). Average fixed oxide charge increased 62.7% from  $2.52e11/cm^2$  to  $6.76e11/cm^2$  after a total of 2 hours  $N_2$  anneal in furnace 13 indicating the presence of Phosphorous ions (Figure 2). Phosphorous outgasses at 300C at atmospheric pressure. Another reason for the increase in the fixed oxide charge as earlier might be the presence of oxygen in the furnace during the anneal that resulted in the increase of the oxide thickness by 12.1% from a starting value of 327A to 372A after a 2 hour  $N_2$  anneal in furnace 13. Average substrate doping declined 12.6% from  $2.21e14/cm^3$  to  $1.93e14/cm^3$  after a total of 2 hours  $N_2$  anneal in furnace 13 (Figure 3). This indicates counterdoping of substrate by n type dopants. The wafer was tested for its type and it turned out to be n type whereas it was p type before the anneal. After that, measurements delivered 600 ohms/square for the Sheet Resistance and 0.6 $\mu m$  for the junction depth. This indicated the formation of a diode. Suprem simulation and Irvine curves indicated a Phosphorous surface concentration of  $1e18/cm^3$ .

The surface concentration of Phosphorous was  $1e18/cm^3$  at 1 atmosphere. At 1100C the solid solubility limit of Phosphorous is  $1.25e21/cm^3$  (Figure 4). Hence, by linear proportionality, the partial pressure of the Phosphorous was  $1.25e21/1e18 = 1.25e3$  and thus  $760 \text{ Torr}/1.25e3 = 0.60 \text{ Torr}$ . This partial pressure is enough to contaminate the wafer with a surface concentration of  $1e18/cm^3$ .

Increase in oxide thickness during the anneals could be because of a possible air leak in the furnaces by which Oxygen got in or because of traces of Oxygen in the cylinders which might not be totally pure.

From the results we can clearly conclude that there definitely are metallic impurities in the furnaces. The highest concentration of metallic impurities seems to be in the furnace used to anneal non conventional materials

like ZnO thin films (furnace 16). Fixed oxide charge also seems to increase in all the furnaces implying the presence of ions and continued oxidation during the anneal. This was most pronounced in the furnace used for wet oxidation and n type doping (furnace 13) indicating Phosphorous ions. Substrate doping was stable in all the furnaces except in the furnace used for wet oxidation and n type doping (furnace 13). Presence of Phosphorous dopant counterdoping in this furnace was proved when the p type wafer annealed in it was tested as n type. These dopants probably outgas and diffuse from the inside of the furnace tubes and get deposited on the wafer surfaces since they have such a high vapor pressure.

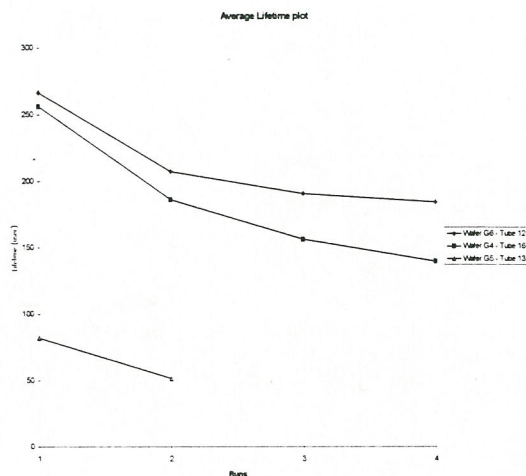


Figure 1

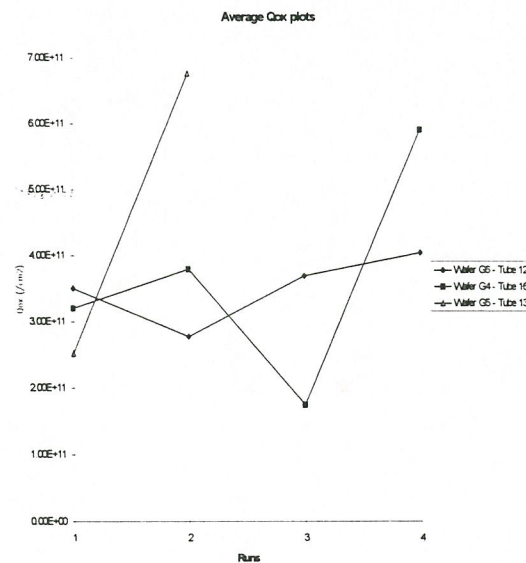


Figure 2

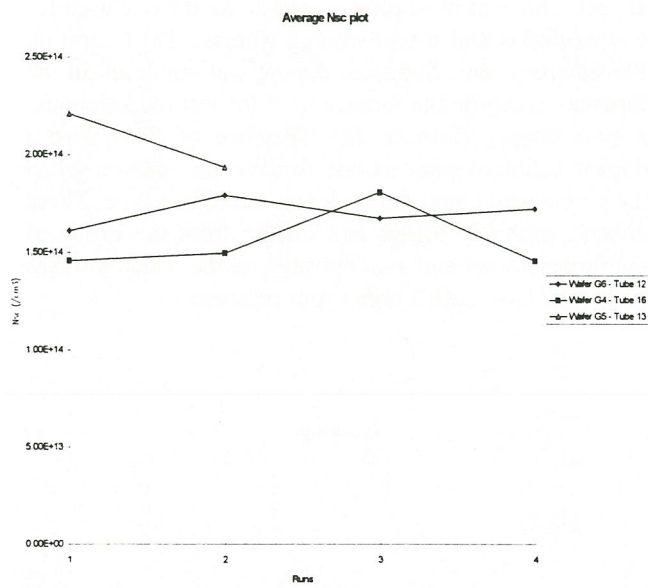


Figure 3

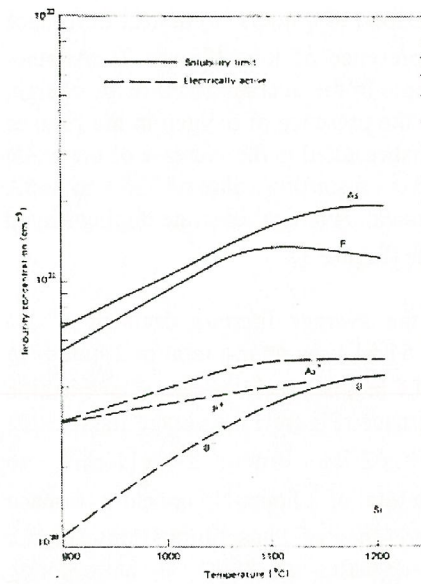


Figure 4

## REFERENCES

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