Characterization of Thermal Oxide Growth Rate on Silicon

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Thermal oxidation is one of the important processes in microfabrication and manufacturing of integrated circuits. It is performed to grow a layer of silicon dioxide on silicon wafers to print design on wafers through photolithography and pattern etching processes. Acknowledging how important this process is, experiments were conducted in TCU Clean Room to investigate the characteristics of thermal oxide growth rate on silicon wafers. The results explored the impact of temperature, wafer orientation inside the gas furnace and locations across the wafer surface on the thickness of silicon dioxide and demonstrated the thin film uniformity.

Introduction

The semiconductor industry is currently one of the most important industries in the world. It focuses on developing the design and fabrication of semiconductor devices such as diodes and transistors and semiconductor materials to contribute to numerous engineering sectors. Because of its enormous impact, engineers are researching new methods and developing materials to manufacture better products. One topic that has high potential to be developed is the microfabrication processes.

This project focuses on the thermal oxidation process which is a way to grow a thin layer of oxide on the substrate. There are two types of thermal oxidation: wet and dry oxidation. The experiments of thermal oxidation were conducted in the thermal oxidation furnace at TCU Clean Room on nine wafers with various placement orientations in the furnace and three different oxidation temperatures: 950°C, 1000°C, and 1050°C. The purpose of this project is to determine if the silicon oxide thickness on silicon wafers is impacted by the temperature, wafer orientation in the gas furnace, and locations across the wafer surface. The thin film uniformity is also investigated by recording the oxide thickness measurements between different locations on the wafer.

How does silicon dioxide form on silicon wafer?

Silicon dioxide or SiO_2 is grown on pure crystalline silicon wafers in the gas diffusion furnace at high temperatures, usually between 800°C to 1200°C, with an oxygen source (for dry oxidation) and water vapor or steam (for wet oxidation) pumped into the system. The oxygen molecules then react with the silicon to grow a silicon dioxide layer in the substrate.

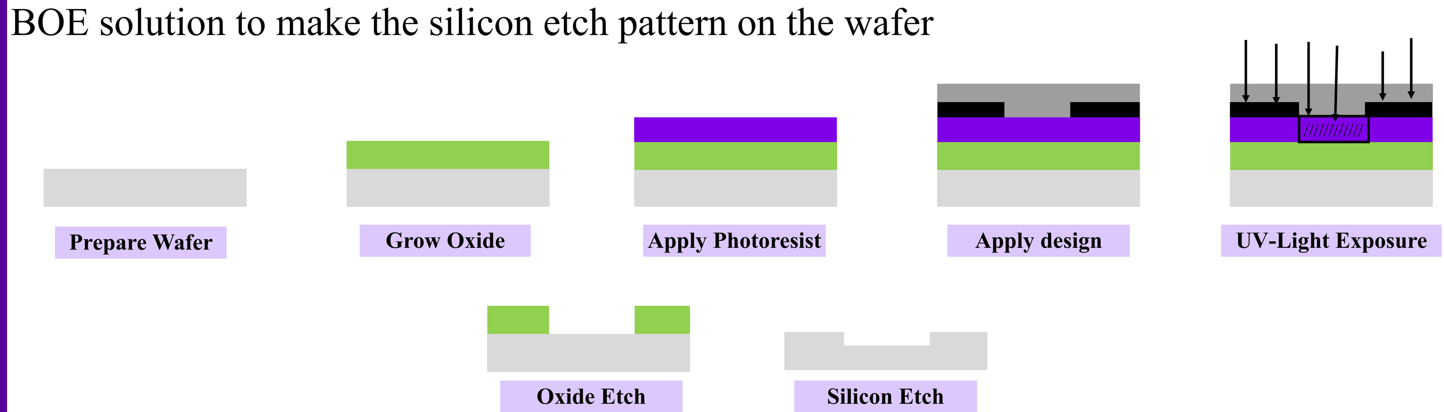
Chemical Reactions

Dry Oxidation: $Si_{(solid)} + O_{2(gas)} \rightarrow SiO_{2(solid)}$

Wet Oxidation: $Si_{(solid)} + 2H_2O_{(vapor)} \rightarrow SiO_{2(solid)} + 2H_{2(gas)}$

How does the thermal oxidation process relate to other processes in microfabrication?

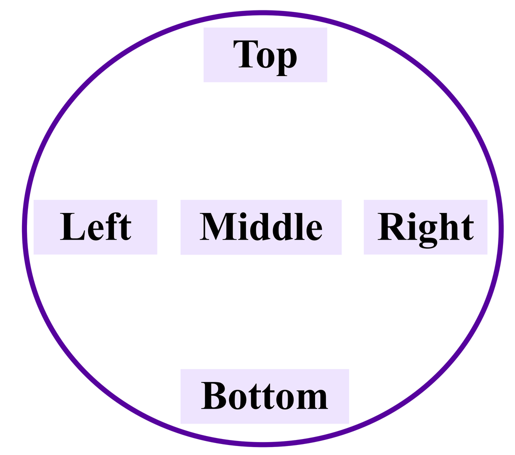
The oxide layer from the thermal oxidation process can helps to determine oxide growth rate and oxide etch rate. It is also the critical step to perform along with other processes in microfabrication to etch design on substrates. Photolithography or UV lithography is a process to transfer the design on wafers by using a photoresist, bake system, and light exposure. The developer and 10:1 BOE solution are used to etch the oxide pattern in the timing based on the oxide etch rate. Finally, the wafers will be put inside the TMAH and 10:1 BOE solution to make the silicon etch pattern on the wafer



Experiment Procedure

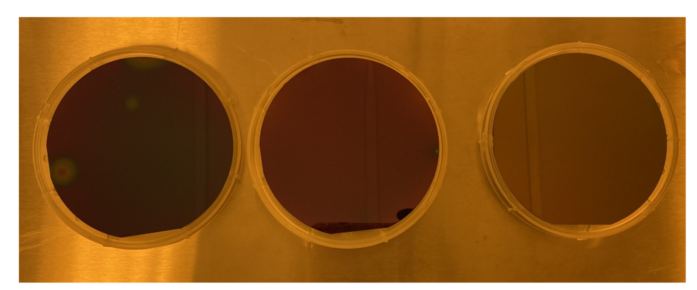
1) Check the gas system and furnace temperature (950°C, 1000°C or 1050°C)
2) Load 3 wafers at fixed spacing and orientation in the furnace
3) Perform dry oxidation 1slm for 5 minutes with O_2 = 1slm
4) Perform wet oxidation for 1 hour using steam in O_2
5) Perform dry oxidation for another 5 minutes
6) Remove wafers and perform measurements using Filmetrics measurement tool

Thermal Oxidation Furnace



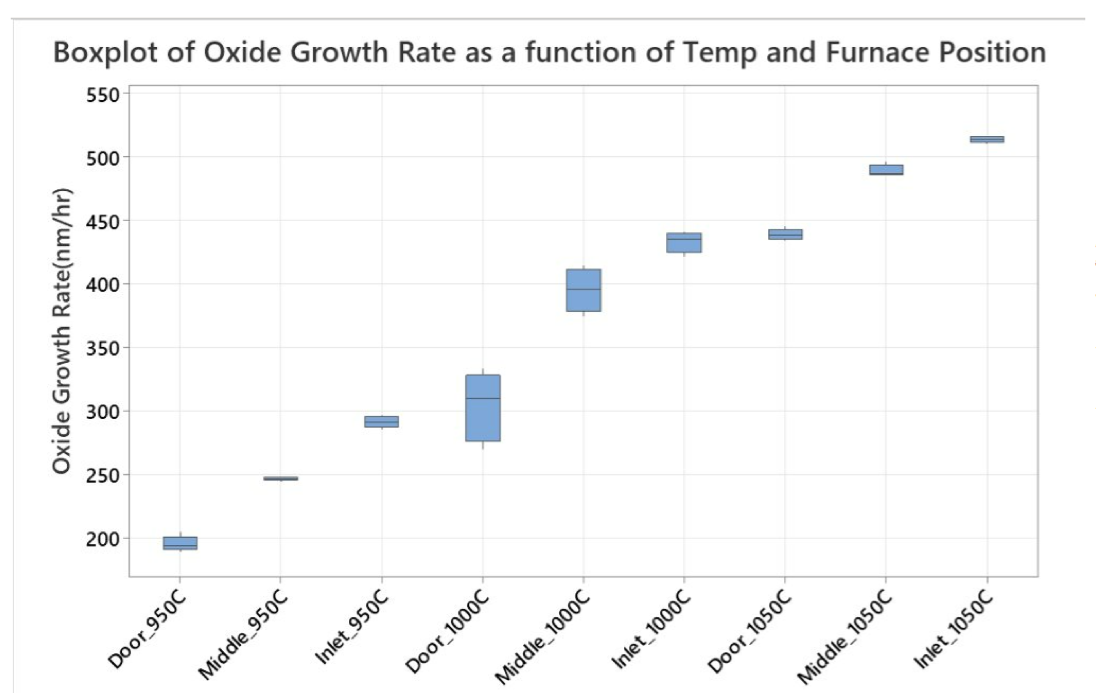
Wafer Measurement Locations

Experiment Results



Silicon wafers after thermal oxidation
Location in the gas furnace
From left to right: Gas Inlet-Middle-Door

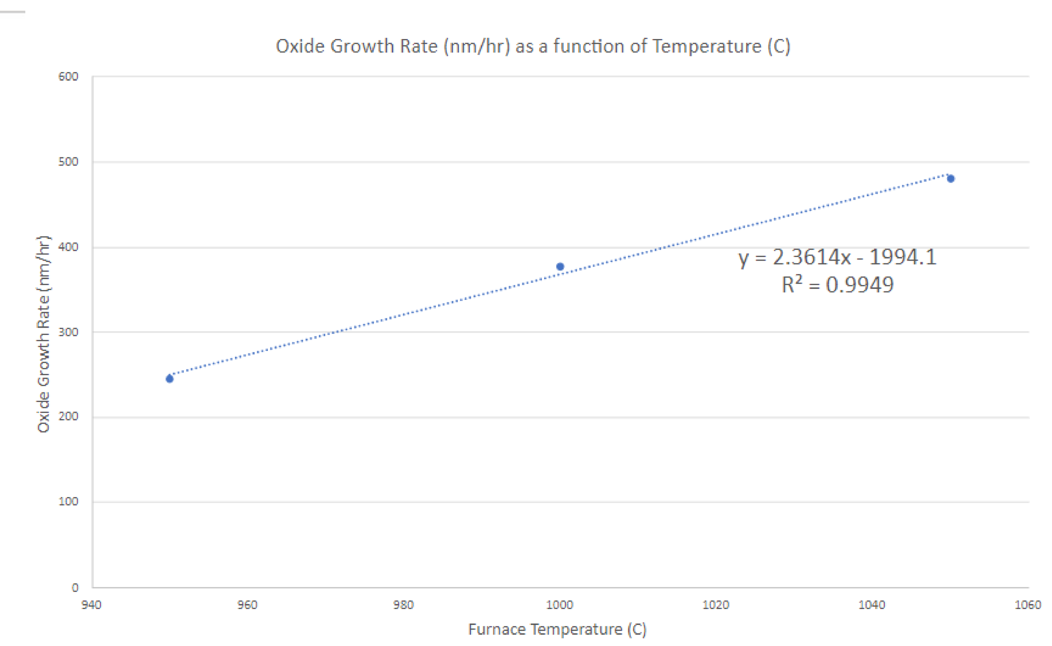
Our attempt to make fun design on silicon wafer by oxide etch



The wafers closer to the gas inlet would grow thicker oxide

T_{trend} **(wafer location)**

$T_{oxide\_inlet} > T_{oxide\_middle} > T_{oxide\_door}$

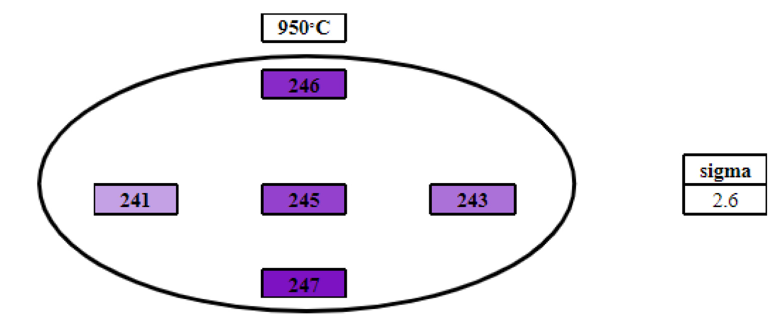


Oxide growth rate increases with increasing temperature

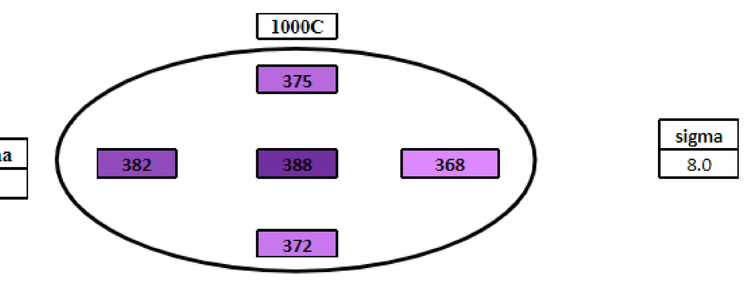
T_{trend} **(temp) = 2.3614(temp)-1994.1**

R^2 **= 0.9949**

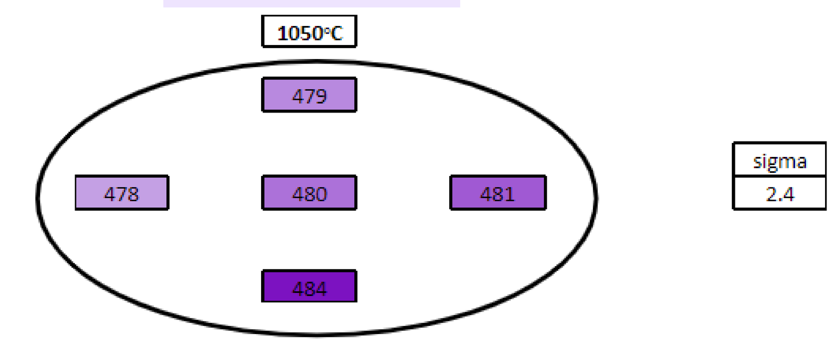
Experiment Results (Continue)



Bottom of Wafer



Bottom of Wafer



Bottom of Wafer

T_{trend}**(wafer location) was uniform with sigma <10nm**

Overall Conclusion

We were able to:

1) Successfully grow silicon dioxide on silicon wafers in a controlled and predictable manner
2) Use a Filmetrics measurement system to measure the oxide thickness
3) Model and verify the oxide growth rate as a function of temperature
4) Analyze the oxide thickness related to the deposition temperature, wafer orientation, and wafer locations
5) Grow a uniform silicon dioxide with a sigma < 10nm across the wafer at all three temperatures

Acknowledgements and References

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