Analysis of Metal Oxide Semiconductor Capacitor with various dielectrics

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***Abstract*—The concept of trench capacitor is widely used in advanced VLSI circuits where maximum data storage is needed.It is a storage node etched into the substrate.Compared to planar capacitor the storage in trench capacitor is more.Also with the different dielectrics, which have different relative permittivities the capacitance varies. Nowadays in some memories,the data is stored in trench capacitors.**

Keywords:Trench,teflon,HFO2

I. INTRODUCTION

In planer parallel plate capacitor,as data storage increases the value of capacitance also increases thereby increasing area of parallel plate.This can be calculated by the formula

$$A_{cap} = \text{cap} \square (t_{dielectric})/\epsilon_{dielectric}) \quad (1)$$

Where $t_{dielectric}$ is dielectric thickness and $\epsilon_{dielectric}$ is permitivity of dielectric In standard circuits of 64Mb DRAM cell size assigned within a chip is 1.25µm^2.According to the above formula for a capacitance of 40fF,assuming SiO2 dielectric thickness of 50A^0.Area calculated will be 5.8 □10¯8cm^2 which is much larger than assigned area. Therefore trench capacitor is the solution to increase the capacitance without increasing the chip area.

The capacitance depends on the voltage that is applied to the gate terminal of a MOS capacior. The Figure 1 shows CV characteristics i.e. the graph of change in charge concentration plotted against applied voltage . Accumulation region in which carriers of the same type as the body accumulates at the surface .Depletion in which the surface is devoid of any carriers leaving only a space charge. Inversion in which carriers of the opposite type from the body aggregate at the surface to invert the conductivity type. [7]

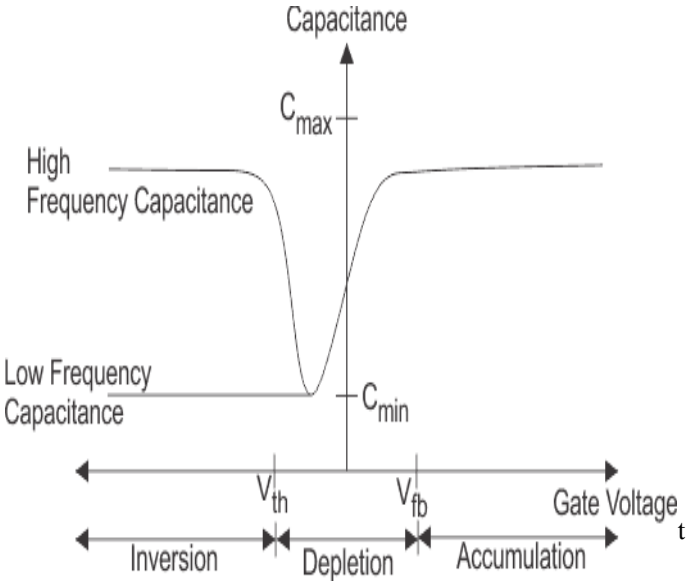

Figure 1. CV characteristics of a MOS capacitor

materials.Simulation results obtained in TCAD simulation software for various dielectrics.

This paper shows implementation of trench capacitor structure using different dielectrics.This simulation is done in VisualTCAD simulation software.

II. OVERVIEW OF CAPACITOR

The capacitors are the basic elements to store data in memory. Basically, there are several types of capacitors some of which parallel plate capacitor and trench capacitor.

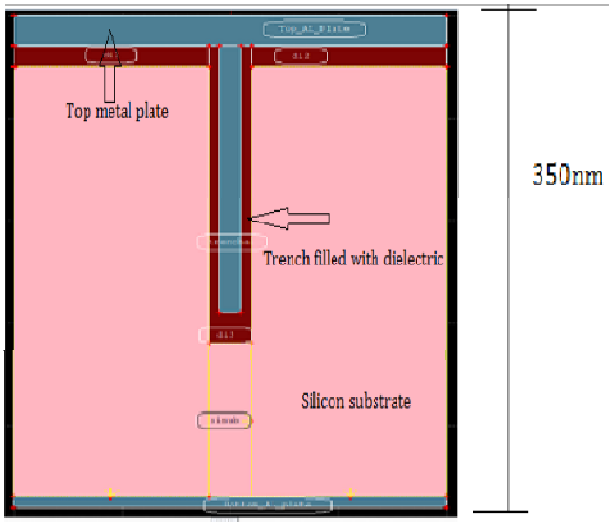

Figure 2. Trench capacitor

a. Trench Capacitor

This capacitor is fabricated using the process of reactive ion etch(RIE),which is creating a deep trench within silicon substrate.The trench side walls are filled with dielectric and then filled with aluminium metal.The doped p^+ substrate acts as a lower plate and the metal acts as upper plate of trench capacitor.As the depth of trench increases the area of capacitor increases,which increases the capacitance values without increasing the chip area. [2]

b. Simulation Methods

The simulation of trench capacitor shown in figure 2 is done using 2D structure for trench depth of 300nm.All the structures are simulated at different frequencies ranging from 10Hz to 1MHz and the applied bias voltage between -6V to 6V.

i. **Overview of different dielectrics.** This paper utilizes 4 dielectrics. [4]

Silicon dioxide(SiO_2):Silicon dioxide is most commonly used dielectric material in VLSI technology because of abundance in nature.The dielectric constant for SiO_2 is 3.9,also ease of fabrication by oxidation process or CVD process.The material has got good stability over wide gap of temperature.

Teflon:This material with dielectric constant of 2.1 is an organic polymer with exemplary temperature stability. It is a synthetic fluropolymer material with melting point of approximately 327 degrees.

Silicon Nitride(Si_3N_4):It is a white high melting point solid which is chemically inert .It is the most thermodynamically stable metal with dielectric constant 7.5.

($HF\ O_2$) Hafnium Oxide :It is an inorganic compound and most stable.Its band gap is 5.3 to 5.7eV.Dielectric constant is 4 to 6 times that of SiO2.
In this paper comparison of C-V characteristic of all above mentioned dielectrics is done for trench capacitance.

III. Results

In this paper, comparison of high capacitance structure with various dielectrics like hafnium oxide,silicon diox- ide,silicon nitride are filled up in the trench.The overall re- sults are carried out using visual TCAD software simulator.

a. i. Dielectric SiO_2 results

The silicon dioxide is the most commonly used dielectric material VLSI technology.1.48 fempto farad is maximum capacitance value is obtained by using silicon dioxide di-electric for the trench capacitor. The figure 3 shows the

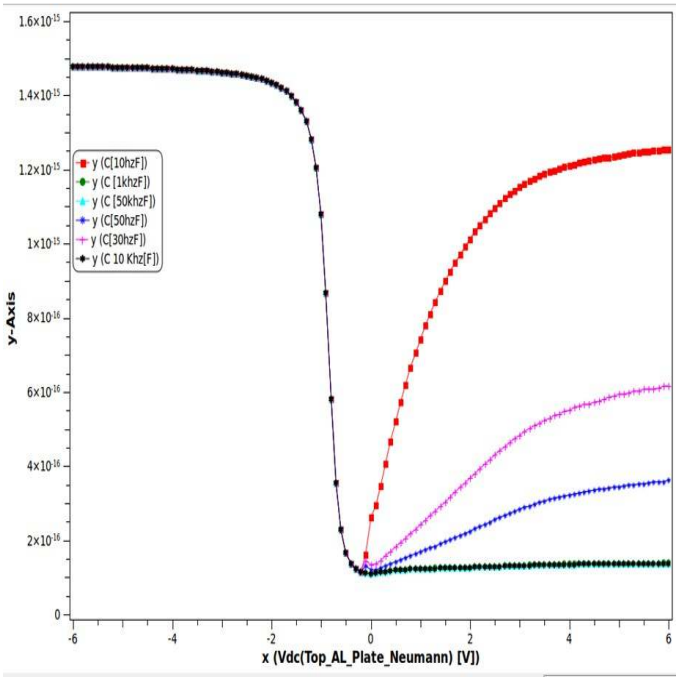

Figure 3. Trench Capacitance values for SiO_2 dielectric for variable frequency

simulation of trench capacitor with silicon dioxide as a dielectric material .The simulation is obtained for various frequencies ranging from 10 Hz to 100KHz.The capacitance is taken from CV characteristics of the curve of change in the surface charge plotted against applied voltage at gate terminal at various frequencies. The maximum capacitance value is 1.5 fempto farads for SiO_2 dielectric material.

ii. Dielectric HF O_2 results

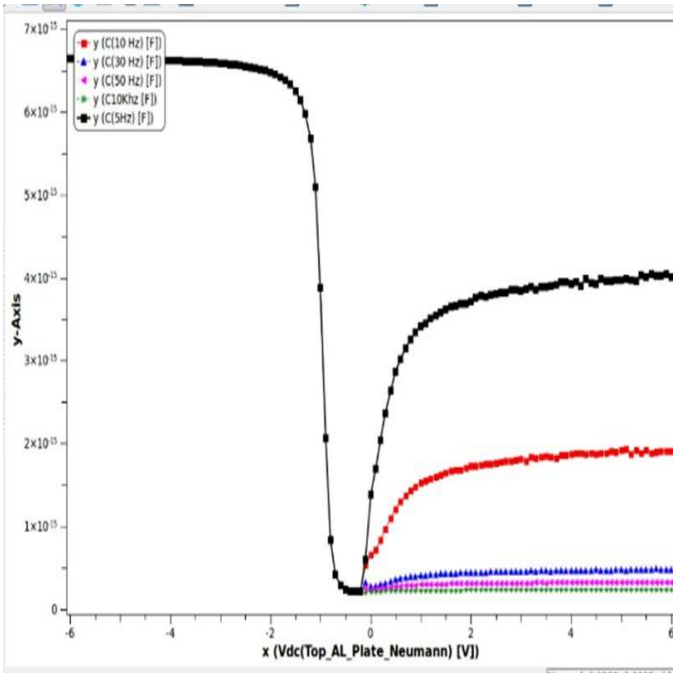

Figure 4. Trench Capacitance values for HFO2 dielectric for variable frequency

Figure 4 shows the simulation of capacitor with insulating material as hafnium oxide which has relative permittivity greater than SiO_2.The maximum capacitance obtained from HF O_2 is 6.6 fempto farads.

Figure 5 shows the simulation of capacitor with insulating material as silicon nitride which has relative permittivity greater than SiO_2.The maximum capacitance obtained from Si_3N_4 is 2.75 fempto farads.

Figure 6 shows the simulation of capacitor with insulating material as Teflon which has relative permittivity greater than SiO_2.The maximum capacitance obtained from Teflon is 8.2 fempto farads.

a. Comparison of capacitances for various dielectric materials

. Table 1 depicts the maximum capacitance values for different dielectric materials

TABLE 1. CAPACITANCE VALUES IN FEMPTO FARAD

dielectric material	Maximum capacitance
SIO2	1.5
Si3N4	2.75
HFO2	6.6
Teflon	8.2

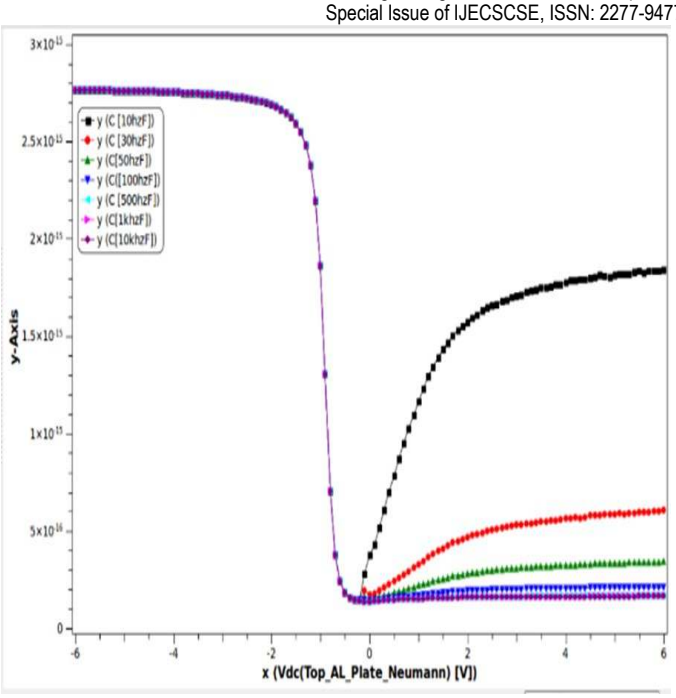

Figure 5. Trench Capacitance values for Si3N4 dielectric for variable frequency

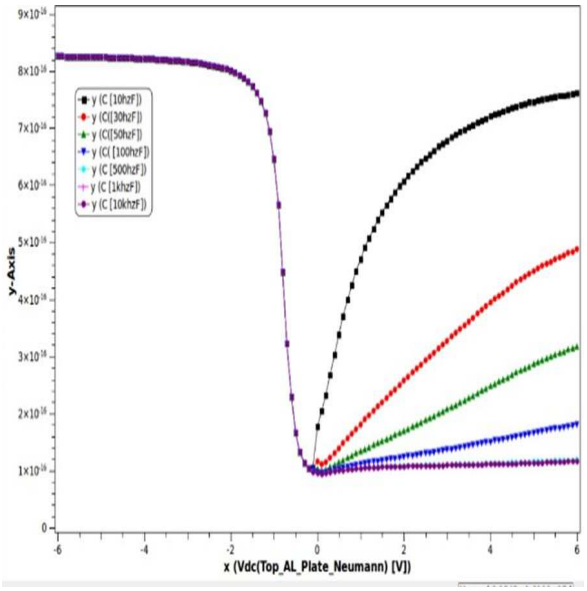

Figure 6. Trench Capacitance values for Teflon dielectric for variable frequency

IV. Conclusion

In comparison with capacitances of all dielectric materials , the value of capacitance increases from SiO_2 to Teflon .This is due to the fact that dielectric constant for teflon and HF O_2 is more compared to SiO_2.

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