Benefits of SiC MOSFETs:

* Can operate at much higher temperatures
* Critical breakdown strength ten times that of Silicon
* Provide higher current density and switching frequencies.
* High electro-thermal conductivity

Switching frequency: A measure of how often a sensor switches on or off per second. It’s the maximum number of switching operations per second. In a MOSFET, it mainly depends on RDS,

MOSFET as a switch:

<https://www.electronics-tutorials.ws/transistor/tran_7.html>

<https://www.instructables.com/Sensor-circuits-with-a-MOSFET/>

The minimum ON-state gate voltage required to ensure that the MOSFET remains “ON” when carrying the selected drain current can be determined from V-I transfer curves.

The drain current ID increases to its maximum value due to a reduction in the channel resistance. ID becomes a constant value independent of VDD, and is dependent only on VGS. Therefore, the transistor behaves like a closed switch but the channel ON-resistance does not reduce fully to zero due to its RDS(on) value, but gets very small.

Likewise, when VIN is LOW or reduced to zero, the channel resistance is very high so the transistor acts like an open circuit and no current flows through the channel.

Accordingly, we define two regions:

1. Cut-off region: Here the operating conditions of the transistor are zero input gate voltage (VIN), zero drain current ID and output voltage VDS = VDD. Therefore, for an enhancement type MOSFET the conductive channel is closed and the device is switched “OFF”. Then we can define the cut-off region or “OFF mode” when using an e-MOSFET as a switch as, gate voltage, VGS < VTH and thus, ID = 0.
2. Saturation region: In the saturation or linear region, the transistor will be biased so that the maximum amount of gate voltage is applied to the device which results in the channel resistance RDS(on)being as small as possible with maximum drain current flowing through the MOSFET switch. Therefore, for the enhancement type MOSFET the conductive channel is open and the device is switched “ON”. Then we can define the saturation region or “ON mode” when using an e-MOSFET as a switch as gate-source voltage, VGS > VTH thus ID = Maximum.

By applying a suitable drive voltage to the gate of an FET, the resistance of the drain-source channel, RDS(on) can be varied from an “OFF-resistance” of many hundreds of kΩ, effectively an open circuit, to an “ON-resistance” of less than 1Ω, effectively acting as a short circuit.

When using the MOSFET as a switch we can drive the MOSFET to turn “ON” faster or slower, or pass high or low currents. This ability to turn the power MOSFET “ON” and “OFF” allows the device to be used as a very efficient switch with switching speeds much faster than standard bipolar junction transistors.

How material is developed

Key advantages

How devices are made using the material

Properties

GaO,GaN,SiC

<https://www.youtube.com/watch?v=ZXDVfZrzsmg>

Introduction:

Semiconductors are essential components in electric devices. They enable advances in communications, computing, healthcare, military systems, transportation, clean energy, and have countless other applications. Since it has such varied applications, research in the field of semiconductors is of utmost importance and can have far-reaching implications.

Motivation:

I’ve always been interested in the field of semiconductors. I wish to investigate the effect of different materials on the working of devices like MOSFETS and thus, improve their efficiency. I feel that semiconductors are one of the more fundamental components of electronics and nothing can function without them. The belief that I would be making an impact on the field of electric devices by working on its fundamental unit motivated me to take up this project.

Current state of art:

At present, Silicon transistors are primarily being used. The two basic types of silicon transistors are MOSFETs and BJTs. However, Silicon devices have certain disadvantages: Electrons aren’t as mobile in it as compared to other materials. This reduces the rate of information travel. Modern ICs use CMOS technology to get around this. However, Silicon’s electron-hole mobility is so low that manufacturers have to boost it by including Germanium with the Silicon. Another problem Silicon suffers from is that its performance degrades at higher temperature. Modern ICs with billions of transistors generate considerable heat, which is why a lot of time and money goes into cooling them. This severely reduces the efficiency of a device in non-ideal conditions. While Germanium offers some advantages, it will be difficult to realign the market around Germanium given that Silicon has been used for decades now. Instead, the way forward is to improve Silicon by integrating it with other materials.

Novelty:

The project will seek to investigate the viability of these compound semiconductors. In fact, two compound semiconductors, SiC and GaN are already available in the market. They offer certain advantages over Si semiconductors.

SiC:

It is a wide band-gap semiconductor that contains equal parts of Si and C atoms in a hexagonal crystal structure. There are two principal kinds of prototypes: 6H-SiC and 4H-SiC. The 4H-SiC model is more commonly used as it displays equal properties along all axes while 6H-SiC is anisotropic.

Benefits of SiC MOSFETs:

* Can operate at much higher temperature. (Greater than 150 degree Celsius—the maximum temperature at which Si can operate)
* Critical breakdown strength ten times that of Silicon.
* Provide higher current density and switching frequencies.
* High electro-thermal conductivity

GaN-on-Silicon:

[Gallium nitride](https://en.wikipedia.org/wiki/Gallium_nitride) (GaN) is a very hard, mechanically stable wide bandgap semiconductor. With higher breakdown strength, faster switching speed, higher thermal conductivity and lower on-resistance, power devices based on GaN significantly outperform silicon-based devices.

Benefits of GaN MOSFETs:

* Devices made in GaN are hetero devices and base their operation on the two-dimensional electron gas (2DEG) that is formed in the quantum well between the heterojunction interfaces.
* This quantum well provides electrons with a highly conductive channel, allowing high electron mobility.
* The use of GaN transistors supports key RF demands such as high gain, low power consumption, high throughput, and extremely fast switching speeds.
* As an amplifier, it provides a much higher bandwidth.

My contribution:

At present, I’m learning to simulate electronic devices using Silvaco TCAD. I am familiarizing myself with the TCAD environment and learning the programming language ATLAS. Once I’m comfortable with the software, I will begin to simulate and develop devices from new materials like SiC and GaN and analyse the change in device parameters with the change in material.

<https://www.electronicshub.org/schottky-diode-working-characteristics-applications/#:~:text=The%20V%2DI%20characteristics%20of%20Schottky,drop%20is%20made%20of%20silicon>.

<file:///C:/Users/tejas/Downloads/Impact_of_doping_on_the_performance_of_P-Type_Be-D.pdf>

<https://www.electronics-tutorials.ws/diode/schottky-diode.html>

<https://silvaco.com/examples/tcad/section22/example9/index.html>

<https://in.ncu.edu.tw/ncume_ee/SchottkyDiode.htm>l

<https://ecee.colorado.edu/~bart/book/book/chapter4/pdf/ch4_4_6.pdf>

<https://www.adsel.ece.vt.edu/files/journal/18.pdf>

<https://www.sciencedirect.com/science/article/pii/S2211379715000856>

<https://www.originlab.com/>

<https://www.adsel.ece.vt.edu/files/journal/12.pdf>

<https://www.eng.buffalo.edu/~wie/silvaco/atlas_user_manual.pdf>

The forward I–V data for both samples is linear on a semi-log scale at lower biases but deviates from linearity at higher biases due to the bulk resistance.

The ideality factor was found to increase with decreasing temperature and increasing carrier concentration

As long as the depletion region remains entirely within the lightly doped epitaxial layer and does not reach the heavily doped n+ substrate, the capacitance and breakdown voltage will be a function only of the epitaxial layer doping and will be independent of the substrate doping.

Code:

# (c) Silvaco Inc., 2018

go atlas

mesh space.mult=1.0

#

x.mesh loc=0.00 spac=0.5

x.mesh loc=3.00 spac=0.2

x.mesh loc=5.00 spac=0.25

x.mesh loc=7.00 spac=0.25

x.mesh loc=9.00 spac=0.2

x.mesh loc=12.00 spac=0.5

#

y.mesh loc=0.00 spac=0.1

y.mesh loc=1.00 spac=0.1

y.mesh loc=2.00 spac=0.2

y.mesh loc=5.00 spac=0.4

region num=1 material=silicon x.min=0 x.max=12 y.min=0 y.max=1

region num=2 material=SiO2 x.min=0 x.max=12 y.min=1 y.max=1.002

region num=3 material=silicon x.min=0 x.max=12 y.min=1.002 y.max=5

region num=4 silicon x.min=0 x.max=8 y.min=1 y.max=1.002

electr name=anode x.min=5 length=3

electr name=cathode bot

#.... N-epi doping

doping n.type conc=5.e16 uniform

#.... Guardring doping

doping p.type conc=1e19 x.min=0 x.max=3 junc=1 rat=0.6 gauss

doping p.type conc=1e19 x.min=9 x.max=12 junc=1 rat=0.6 gauss

#.... N+ doping

doping n.type conc=1e16 region=3 uniform

#doping n.type conc=1e16 region=1 uniform

save outf=diodeex01\_0.str

model conmob fldmob srh auger bgn

contact name=anode workf=4.97

solve init

method newton

log outfile=diodeex01.log

solve vanode=0.05 vstep=0.05 vfinal=1 name=anode

tonyplot diodeex01.log -set diodeex01\_log.set

quit