2. SiC and GaN TECHNOLOGY

Silicon carbide (SiC) is made up of equal parts silicon and carbon. The both are period IV elements. Gallium Nitride (GaN) is a strong semiconducter composed of gallium and nitrogen. They are wide band gap semiconducters having compound structure. So they are called as "Compound Semiconducters".

As depicted in Table I (in presentation slides), some parameters summarize the superior performance over conventional silicon devices.

* SiC and GaN devices have enormous advantage compared to conventional Si devices such as;
* Higher power ratings
* Operation at higher frequency levels
* Increased power density
* Reduction in size
* Lower cost (overall cost)
* Higher efficiency

GaN has the highest electron mobility that makes it the optimal solution for high frequency applications. Since SiC has the highest thermal conductivity, it can operate at high temperatures and power ratings. It is needed to analyze the comparison parameters to clarify the key performance advantage

WIDE BAND GAP (WBG) SEMICONDUCTERS

The band gap refers to the energy difference between the top of the valance band and the bottom of the conduction band.

The band gap represents the amount energy needed for electron to successfully make the jump between the valance band and the conduction band.

When the temprature increases, electrons are excited to the conduction band and the leake current increases. Higher band gap width prevents the leakage current and enables operation at high temperatures.

Since wide band gap semiconducters have small lattice constant, the bond strength between atoms become strong. This means high electric break-down field and thermal conductivity. The operation at high temperature and increasing thermal conductivity diminish the need for cooling and so the sink size reduces to lower values. It means the increase of power density.

This larger energy gap (or wider band gap) gives these meterials superior qualities such as faster switching, higher efficiency and increased power density.

BREAKDOWN ELECTRIC FIELD

Since WBG semiconducters have strong covalent bonds, It is possible to operate SiC and GaN devices at higher breakdown voltage. In addition, doping concentrations can be made higher than conventional applications. So drift layers can be made thin.

The value of resistance of any power switch is directly in proportion to the thickness of the drift layer.

Because of the thin drift layer, low turn-on resistance and high voltage power devices can be fabricated.

The turn-on resistance $R_{DS_{ON}}$ is one of the major drawback of Mosfet Power Switch since it causes to power loses. The power lose due to high $R_{DS_{on}}$ is the biggest one among other power loses. As a result of lower $R_{DS_{ON}}$, the efficiency of the system will be higher.

ELECTRON MOBILITY

Electron mobility has a substantial impact over the speed of the power switch. The higher electron mobility enables us to obtain a quick responce, faster switching and transition between on and off states.

Electron mobility characterizes how quickly an electric field can accelerate the velocity of an electron.

Velocity (V) = Mobility (μ) x Electric Field (E)

$\mu = \frac{V}{E}$ unit $\frac{cm^2}{V \cdot s}$ or $\frac{m^2}{V \cdot s}$ in SI system

Higher mobility means that an electric current flows more easily, resulting in lower resistance.

The maximum velocity attainable is called as the saturation drift velocity which is another parameter to compare the performance differencies of SiC and GaN.

SATURATION DRIFT VELOCITY

A switching period of any power switch comprises two section as turn-on and turn-off durations. The turn-off time is called as the reverse recovery charge duration as well.

When the saturation drift velocity value is higher than conventional si semiconducters, the turn-off time and switching period is going to be shorten as a conclusion.

This condition enables us to operate power switches at high frequency values. By considering the equations for inductive reactance and capasitive reactance,

$$X_L = 2 \cdot \pi \cdot f \cdot L$$

$$X_C = \frac{1}{2\pi \cdot f \cdot C}$$

thanks to high frequency values, we will able to select small inductance and capasitor sizes. This opportunity results in the drease of size of the converter we are interested in. Besides, we obtain substantial decrease in the project cost.

THERMAL CONDUCTIVITY

The combination of the higher thermal condutivity and operation ability at higher temperature values eleminates the need for cooling problem for power switches. It increases the heat dissipation of power switches

The major benefit of this ability is reducing size of power converter. It means the cost reduction and power density increase as well.