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Research Paper

COMPARATIVE STUDY OF GaN AND GaAs MESFET

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In the information, science and technology such as computer science, telecommunication, processing of the signals or images transmission the field effect transistor plays a major role. In this paper, we have determined the comparative study of various qualities of GaN and GaAs MESFET here we have presented the result of calculating the influence of gate length on input and output impedance of GaAs and GaN MESFET, these two physical models are based on the analysis of iterative method in the active region under the gate. The theoretical results based on analytical expression that we have established are discussed and compared with those of result.

Keywords: Image transmission, Iterative method, Influence of gate, Telecommunication, Gate lengths

INTRODUCTION

The properties of III-V nitride heterostructures are attracting increasing attention for a wide range of device applications, including blue, green, and ultraviolet LED's, short wavelength lasers, and high power, high temperature, and high frequency electronic devices. There are three important binary nitride materials: AIN, GaN, and InN. Among these, GaN shows great promise for microwave applications. The wide energy band gap of GaN (3.43 eV, as compared to 1.4 eV for GaAs) leads to low intrinsic carrier concentration over a wide range of temperatures. This in turn allows GaN based devices to be operable at high temperatures. Also this wide band gap allows very high electric breakdown fields (1.5×10^7 V/m as compared to 2.5×10^5 V/m for GaAs). As a result GaN based devices can be biased at very high drain voltages (breakdown voltage = 50-500 V depending on the application), and because of the large thermal conductivity of GaN (1.7 W/cm. K as compared to 0.46 W/cm. K for GaAs), the channel temperature can reach 300 °C. Even though the low-field mobility is not high (the best value reported so far for GaN is about 2000 cm^2/V.s as compared to a value about 8500 cm^2/V.s for GaAs), it is not very sensitive to ionized impurity concentration. Furthermore, a larger peak velocity can be reached (2.7×10^7 cm/s at room temperature as compared to 1.5×10^7

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cm/s for GaAs), which permits high currents and high operating frequencies. The energy band gap difference between AlN and GaN is also quite significant (e.g., 2.57 eV, as compared to 0.73 eV for GaAs and AlAs), which permits high concentrations of free carriers to be confined at the AlGaN/GaN hetero interface paving the way for the high performance AlGaN/GaN high electron mobility transistor.

GaN-based microwave power MESFETs have defined the state-of-the art for output power density and have the potential to replace GaAs-based transistors for a number of high power applications. The GaN-based material system, consisting of GaN, AlN, InN and their alloys, has become the basis of an advanced, microwave-power-device technology for a number of reasons. GaN has a breakdown field that is estimated to be 3 MV/cm, which is ten times larger than that of GaAs, and a high peak electron velocity of 2.7 x 10^7 cm/s.

As a result of these properties, excellent high-frequency, high-power performance has been achieved with GaN based MESFETs. Although significant progress has been made in the past few years, additional developmental work is required for GaN MESFETs to become a viable technology. This paper examines the microwave frequency applications of GaN MESFET. Starting from I-V characteristics, I analyzed properties using physics based model for GaN. Various possible impacts of the parasitic resistances and capacitances are considered, with emphasis to discuss the potential applications of GaN MESFET and a better realizable design

THEORETICAL ANALYSIS

GaN FETs are known to be a wide band gap semiconductor material with a high breakdown electric field, high saturation drift velocity and better thermal conductivity in comparison with the more commonly used GaAs and SiC MESFETs.

The current voltage characteristic of MESFET shows the comparison among the two devices which can be seen from the theoretical analysis that GaN based devices are better for high power devices where the other GaAs devices where fails to withstand high temperature and power.

The current-voltage relationships of a MESFET are illustrated in Figure 1. The channel current is plotted as a function of applied drain-source potential for different gate-source voltage levels. Three regions of operation can be identified from the figure. They are the linear region, the saturation region and the breakdown region. In the linear region, current flow is approximately linear with drain voltage. As drain potential increases, the depletion region at the drain end of the gate becomes larger than at the source end. Since the device is taking constant current through the channel region, the electrical field increases as the channel region narrows, and therefore a related increase in electron velocity occur.

However, if the gate reverse bias is increased while the drain bias is held constant, the depletion region widens and the conductive channel becomes narrower, reducing the current. When Vgs = Vp, the pinch-off voltage, the channel is fully depleted and the drain current is zero, regardless of the value of Vds. Thus, both Vgs and Vds can be used to control the drain current. When the MESFET is operated under such bias voltages, where both Vgs and Vds have a strong effect on the drain current, it is said to be in its linear or voltage controlled resistor region channel near the drain becomes narrower, the electrons must move faster.

However, the electron velocity cannot, increase indefinitely; the average velocity of the electrons in GaAs cannot exceed a velocity called the saturated drift velocity, approximately 1.3 x 10^7 cm/s. If Vds is increased beyond the value that causes velocity saturation (usually only a few tenths of a volt), the electron concentration rather than velocity must increase in order to maintain current continuity. Accordingly, a region of electron accumulation forms near the end of the gate. Conversely, after the electrons transit the channel and move at saturated velocity into the wide area between the gate and drain, an electron depletion region is formed.

Figure 1: Current-Voltage Characteristics of MESFET

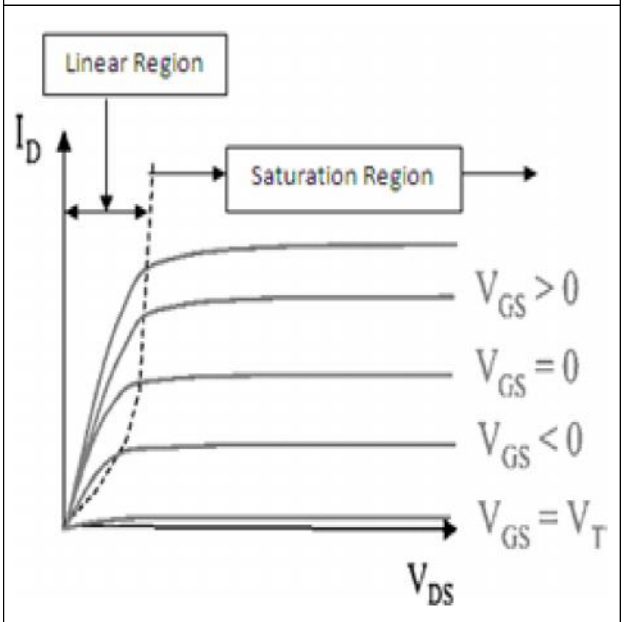

Table 1: Properties of GaN and GaAs

Material Properties	GaAs	GaN
Band gap (eV)	1.43	3.4
Electron Mobility (cm^2/V-sec)	8500	2000
Electron Saturation Velocity (10^6 cm/sec)	12	25
Thermal Conductivity (Watts/cm. K)	0.5	1.3
High/Low Power Device	Low	High

The fundamental physical limitations of Si operation at higher temperature and powers are for these applications. For phase array radars, wireless communication market and other traditional military applications require demanding performance of microwave transistors. In several applications, as well as in radar and military systems, the development of circuits and sub-systems with broadband capabilities is required. From transmitter point of view the bottleneck, and the critical key factor, is the development of high performance PA.

Next generation cell phones require wider bandwidth and improved efficiency. The development of satellite communications and TV broadcasting requires amplifiers operating both at higher frequencies and higher power to reduce the antenna size of terminal users. The same requirement holds for broadband wireless internet connections as well. This high power and high frequency applications require transistor with high breakdown voltage, high electron velocity and high thermal conductivity. The wide band gap materials, like GaN and SiC are preferable.

The most important factor that characterize the properties of GaN MESFET can be give by its current voltage characteristic.

This work has been conducted by the physics based analytical model. So far, many analytical model has been developed to evaluate the I-V characteristics, where the model for I-V characteristics cannot combine the non-saturation and saturation region (linearity and non-linearity regime).

Thus the same can be explained for the GaAs mesfet by getting the I-V characteristic we can compare the performance of two materials.

I-V CHARACTERISTIC OF GaN MESFET

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The current voltage characteristic has been evaluated by new imperial equation.

$$Ids = (Vgs - Vto)^2 * (1 + Vds) * \tanh(\sim Vds)$$

Thus the result will be given in Figure 3.

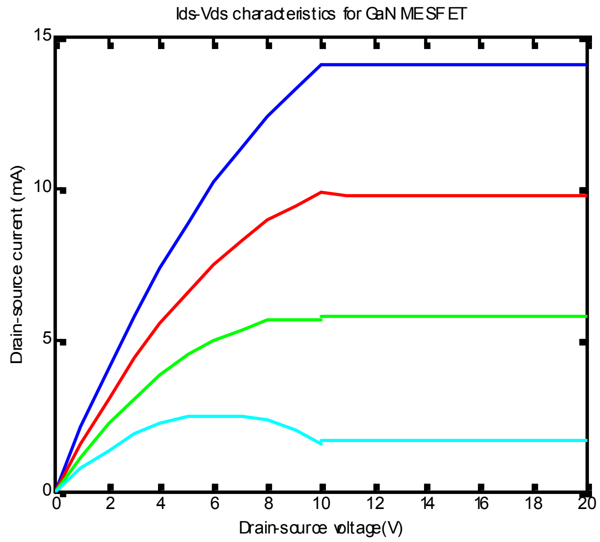
Thus the current voltage characteristic of two material has been shown in the two analytical model.

RESULTS AND DISCUSSION

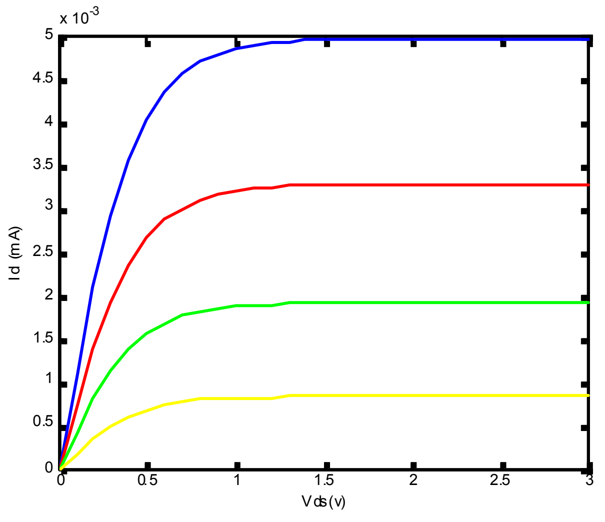
The analytical model of GaAs MESFET has been developed to evaluate the I-V characteristics, and extrinsic parameters: gate-source capacitance and gate-drain capacitance. This model incorporates a new empirical equation for simulating the bias dependence junction capacitance of GaAs MESFET. The results of gate-source capacitance and gate-drain capacitance show an improvement of device performance by incorporating the new empirical equation. But in comparison with that of GaN MESFET it does not shows the non-saturation and saturation region (linearity and non-linearity regime).

In GaN MESFET the present work shows an tremendous impact of numerical iterative to find the I-V characteristics of GaN MESFET in linear and non-linear regions where parasitic resistance has been considered which is helpful for the high power and high temperature microwave devices.

Figure 2: Ids-Vds Characteristics of GaN MESFET



Figur 3: Plot of Current Voltage Characteristics of GaAs MESFET for Different Gate-Source Biasing



CONCLUSION

In this work, we have developed the transport model to analyze the performance of two material device with there analytical models thus the result conclude GaN to be the best suitable material for high frequency microwave applications.

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