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Performance comparison of GaN and Si FinFETs

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Abstract: This paper presents a detailed comparative analysis of the Si and GaN-based FinFETs. Both devices are simulated using TCAD tool for analysis. The GaN FinFET shows considerably better performance at high voltages and higher temperatures than the Si FinFET. The threshold voltage for GaN FinFET is 0.4V whereas for Si FinFET threshold voltage is 0.6V. The high electron mobility and wide bandgap of the GaN material make the GaN-based devices very useful for future high-power applications.

IndexTerms: **GaN FinFETs, high voltage, high temperature, high electron mobility**.

I. INTRODUCTION

Gallium nitride (GaN) has been the material of choice in the field of power electronics and radio frequency (RF) applications where silicon (Si) may not be useful due to the limitations in the material parameters [1]. The characteristics like wide bandgap, very high critical electric field, and rapid saturation velocity of GaN make it a better material for applications involving high-voltage, high-frequency, and high-power [2]. Although commercial GaN devices are being more widely used in defence applications, telecom, consumer electronics, electric vehicles, and data centres [3]. Because of its good controllability of short channel effect (SCE) and little variability, the Fin field-effect transistor (FinFET) is a potential device shape for scalable CMOS logic/memory applications at 22 nm technology and beyond [4, 5].

In recent years, the FinFET and trigate architectures have been employed to create a new generation of GaN power and RF devices, advancing the state-of-the-art in the power electronics and microwave areas. Due to higher current on/off ratios, steeper threshold swings, and suppression of short-channel effects, these fin-based GaN devices have enabled enhancement-mode operation, on-resistance reduction, current collapse alleviation, linearity improvement, higher operating frequency, and improved thermal management. On the other hand, due to challenging fin/gate patterning in the Due to the 3D structure, conformal doping to fin, and high access resistance in an incredibly thin body, finFET fabrication presents a number of process problems.

In this paper, we have presented a comparative study of the device characteristics of Silicon and GaN-based FinFETs. The drain current and transconductance of GaN-based FinFET are much higher than silicon-based FinFET indicating the intriguing research potential in this fast-paced field.

II. DEVICE SIMULATION

The 3D structure of Si FinFET and GaN FinFET are designed with the same dimensions using the Silvaco ATLAS TCAD tool [6]. In Fig. 1 the 3D structures are shown for both. Though the materials are different in both types of FinFET, the device dimensions are the same. For the GaN FinFET, we have taken Al2O3 as the oxide material and gold (Au) as the gate electrode whereas the Si FinFET uses SiO2 and polysilicon as the oxide and gate electrode respectively. The device geometry parameters are shown in table-1.

Table 1. Device dimensions of Si and GaN channel FinFET.

Parameters	Values
Height of Fin	15nm
Width of Fin (top & base)	10nm
Channel Length	30nm
Thickness of Oxide	2nm
Channel Doping	1x1018 cm-3
Source/Drain Doping Concentration	1x1021 cm-3

Bandgap of GaN is given by

$$E_g(GaN) = 3.507 - \frac{0.909\times10^{-3}T^2}{T+830} \qquad (1)$$

For the simulation of GaN FinFET, the electron mobility as a function of lattice temperature and doping is described following the analytical model developed by Albrecht et al. [7]. For the Si FinFET, the BQP model (Bohm Quantum Potential model) is included in the simulation to analyze the quantum confinement effect [6].

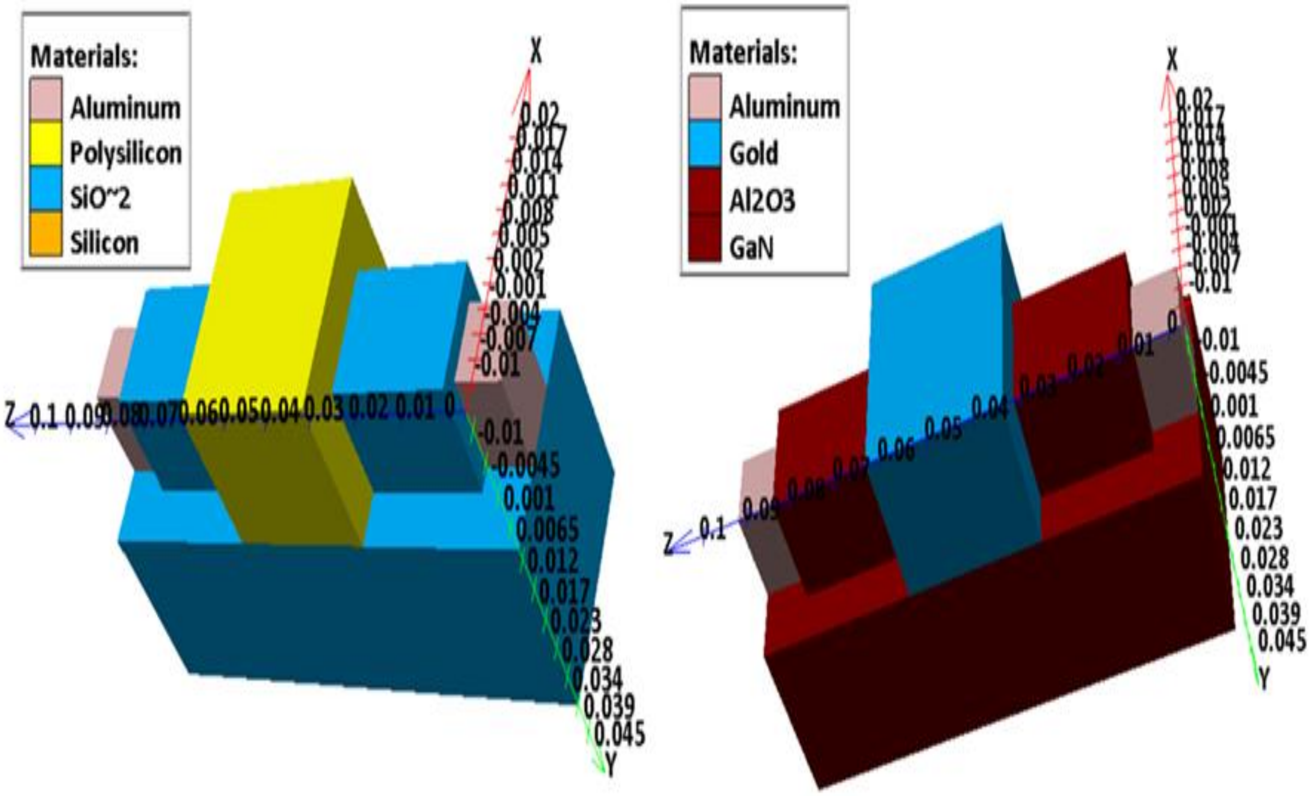

Fig. 1. Structure of Si FinFET and GaN FinFET.

III. RESULT AND DISCUSSION

The transfer characteristics and output characteristics of Si and GaN FinFETs have been compared which shows significant performance enhancement for the GaN channel devices. In Fig. 2, the I_D vs V_{GS} characteristic of Si and GaN FinFET is shown. The threshold voltage of the GaN fin device is almost 0.2V less than the Si fin device which ensures faster operation for the GaN-based FinFETs. Similar characteristics are observed for the transconductance curves in Fig. 3. The higher peak transconductance value of the GaN FinFET is due to the high mobility of the carriers in the GaN channel.

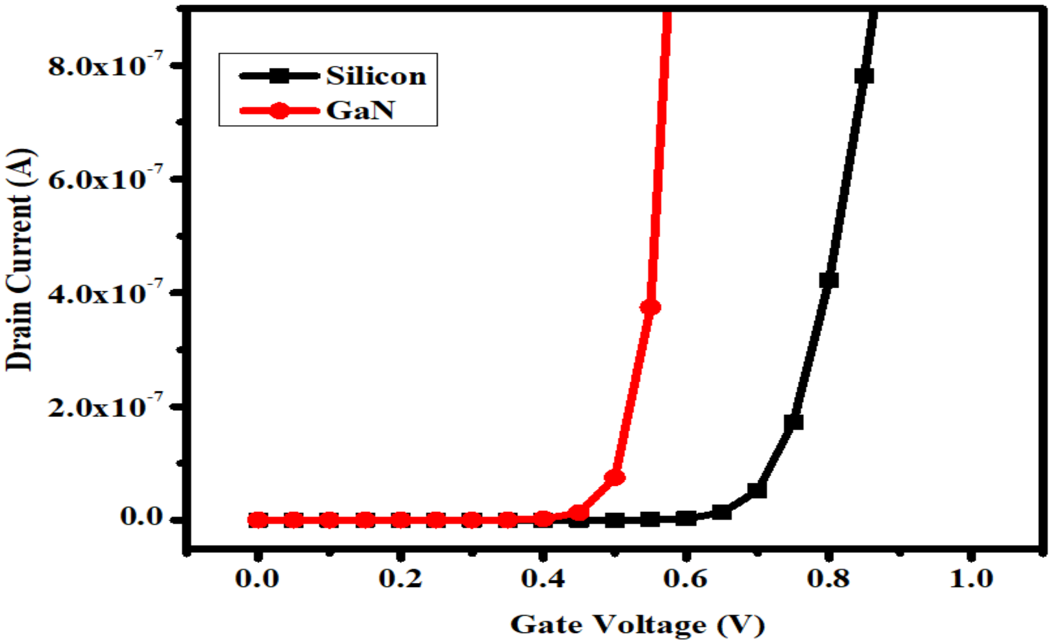

Fig. 2. Comparison of transfer characteristics of Si FinFET with GaN FinFET.

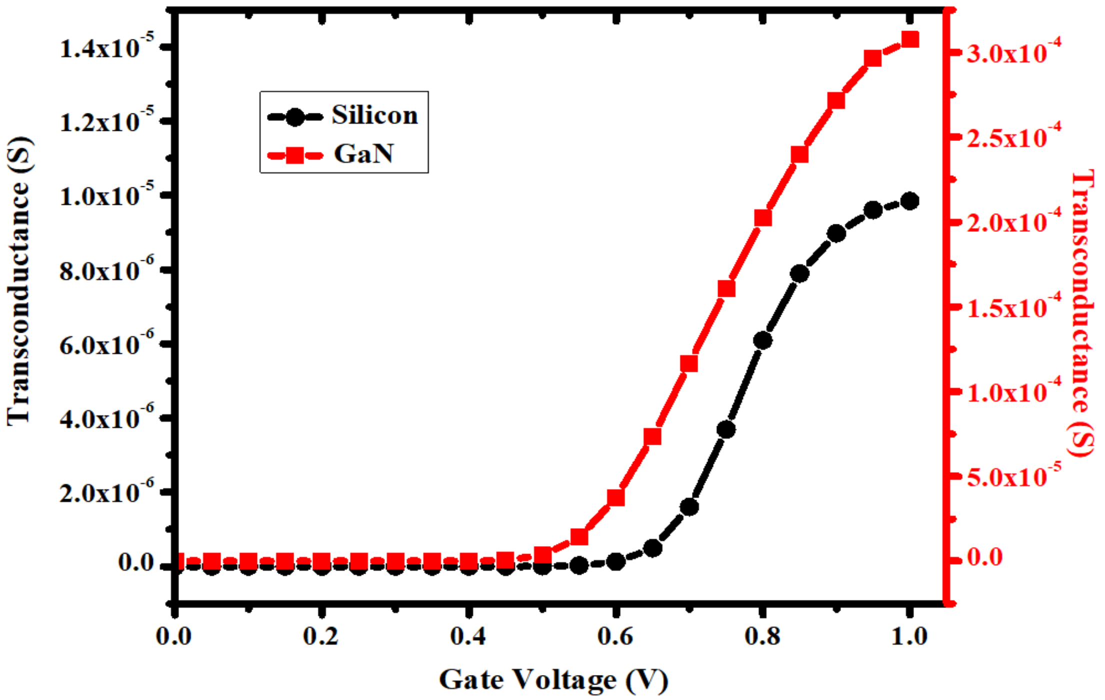

Fig. 3. Transconductance comparison of Si and GaN-based FinFET.

Fig. 4 represents the comparison of transfer characteristics of the GaN and Si channel FinFET at a higher temperature of 473K. Due to the high thermal conductivity of the GaN-based devices, similar enhancement in characteristics is observed even at a higher temperature for the GaN FinFET.

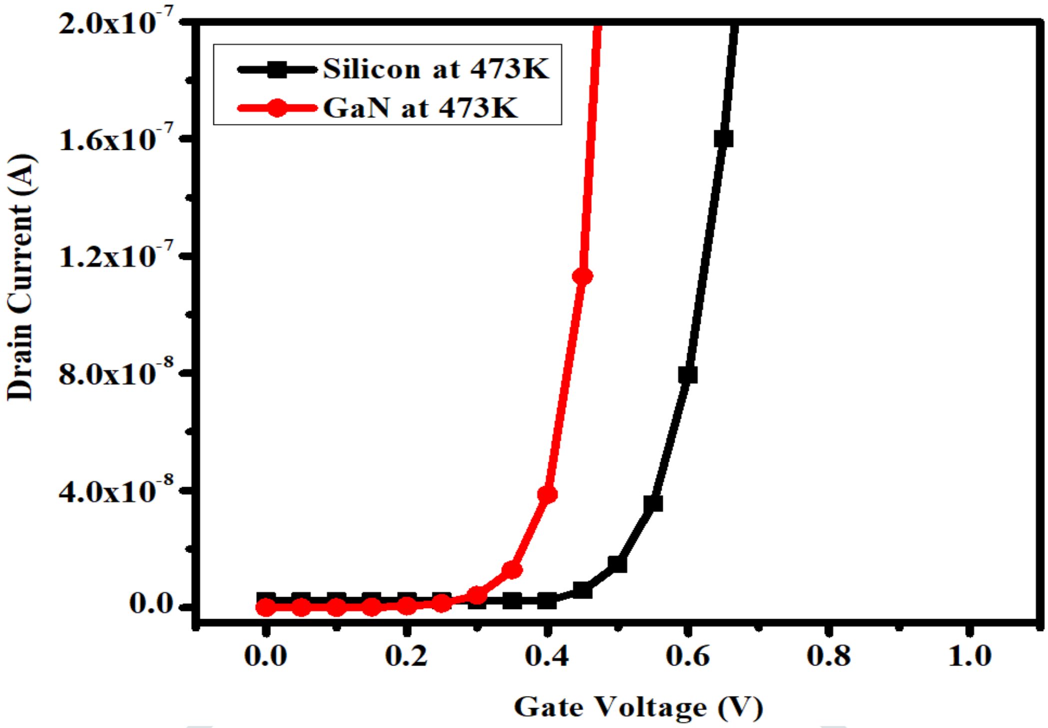

Fig. 4. Comparison of transfer characteristics of Si and GaN FinFET at 473 K.

The I_D-V_D characteristics of the GaN FinFET for different values of gate voltages are presented in Fig. 5. Due to the wide bandgap of GaN, the GaN-based devices can withstand very high voltages without breakdown which makes them useful for high power and high voltage applications. Fig. 6. Shows the comparison of I_D-V_D characteristics of Si and GaN channel FinFETs at V_{GS} = 1 V. As the drain voltage increases, the current in GaN FinFET increases at a higher rate and is almost 5 times higher than the current in Si FinFET at V_D = 1V.

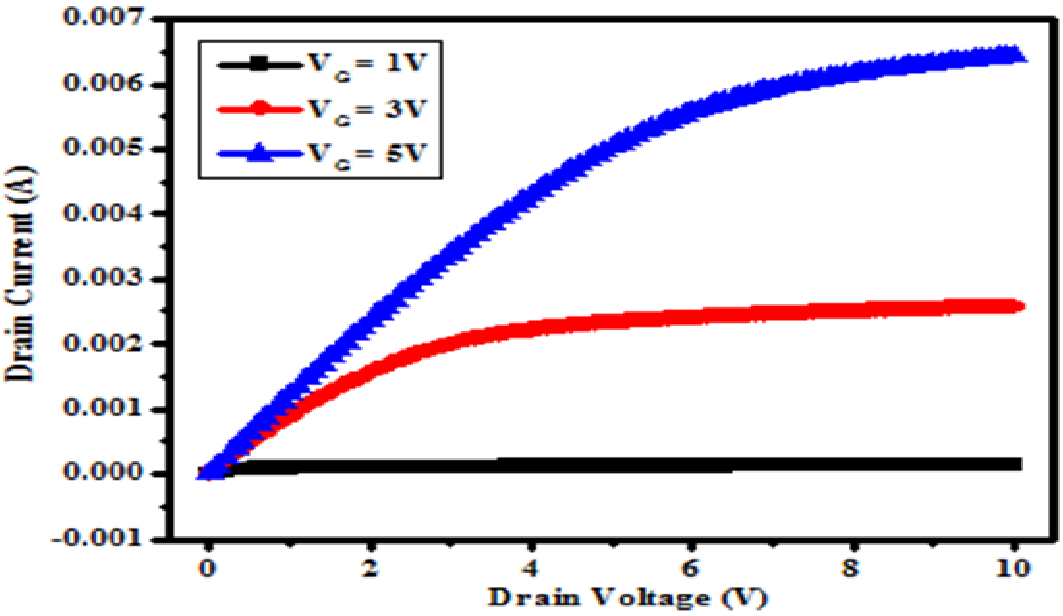

Fig. 5. I_D-V_D of GaN FinFET for different gate voltage V_G = 1V, 3V, 5V.

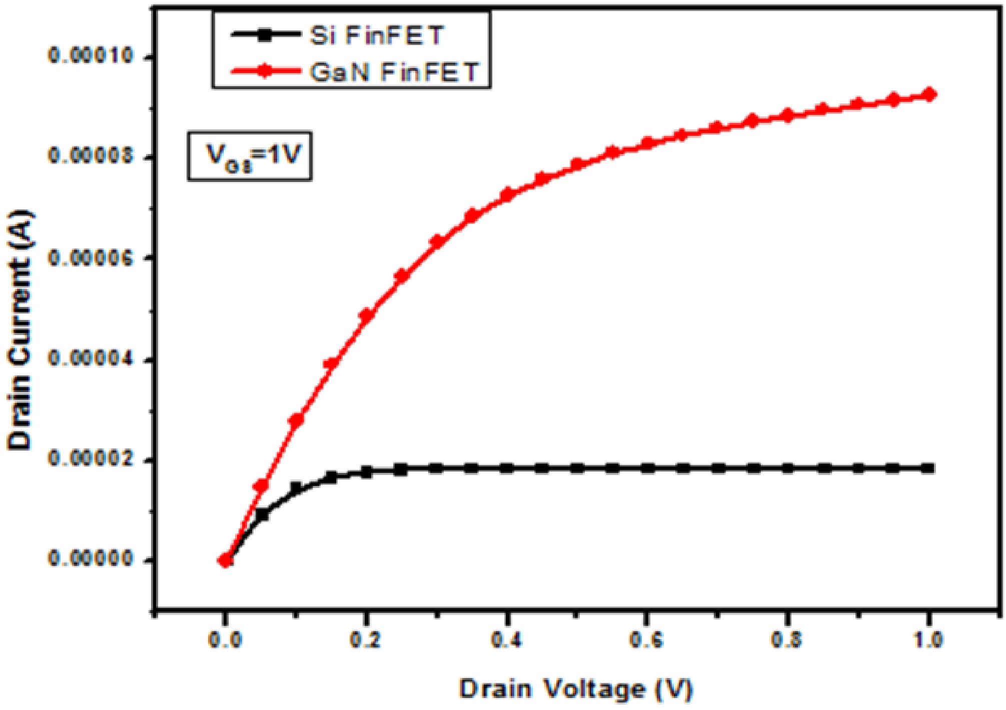

Fig. 5. Comparison of I_D-V_D characteristic of Si and GaN FinFET at V_{GS} = 1V.

IV. CONCLUSION

In this paper, a detailed comparison of the dc characteristics of Si and GaN FinFETs with the same dimension has been presented. The I_D-V_G characteristics of GaN and Si FinFET are analyzed at room temperature 300 K and high temperature of 473 K. The output characteristics, I_D-V_D have been analyzed at V_G = 1V. From the analysis, it is shown that the GaN FinFET shows significantly higher drain current and transconductance at high voltages and higher temperatures than the Si FinFET. These are attributed to the high electron mobility and wider bandgap of the GaN material. The results show the effectiveness of GaN-based devices for high voltage and high-temperature applications.

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